SOURCES OF AGRICULTURAL PRODUCTION AND PRODUCTIVITY IN COLOMBIAN AGRICULTURE

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PREFACE

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CHAPTER I

INTRODUCTION

General Characteristics and Problems of Colombian Agriculture

In the past decade agricultural productivity has been the subject of study by economists interested in analyzing its nature and causes in many countries. The major objective has been to provide a framework for understanding the process of productivity. This attention has been a consequence in large part, of the increasing demand for policy guides designed to increase production. Resulting policies affect the rate of productivity change and the production levels in private industries and overall economic growth. The greater the proportion of a country's labor force that is employed in the agricultural sector, and the greater a country's dependence upon agricultural exports to earn hard currency, the more important it is to achieve productivity gains which keep production costs at competitive levels and output sufficiently high to meet both domestic and foreign demand.

It has been recognized that productivity increases (in the output-input ratio) are very important indicators of economic growth for industries and the entire economy. Consequently, the analysis of productivity change has assumed an increasingly important role. As Barter [11, p. 582] has pointed out, this kind of analysis can contribute to a better understanding of the factors that contribute to economic growth. Therefore, production studies are especially necessary to provide better policy guides in the developing countries throughout the world. Colombia has great potential for increasing agricultural productivity simply because current productivity levels are so low. Low productivity is manifested by poor crop and livestock yields relative to other countries. Yields of wheat, maize, rice, potatoes and dry beans in Colombia, for instance, are less than one-half those obtained in countries such as the United States, Canada, or Japan. Only a few products such as sorghum and cotton (lint) can compare favorably with other countries (Table I). Milk yield per cow is among the lowest in the world. In beef production the rate of extraction in 1969 was 14.2% in Colombia, whereas that of the United States was 30.0%, Argentina 25.3% and Australia 23.0%.[1] More recent data [64] indicate that yields vary widely among products over time. Generally, such differences could be expected to exist in any country, but the large magnitudes of differences in Colombia signal important implications for agricultural policy.

The need for improved agricultural productivity (generally defined as an increase in the output-input ratio) is paramount given the high annual rate of population growth, estimated at 3.2%. Moreover, it is a fact that low agricultural productivity in general is a serious constraint to the industrialization and economic growth of Colombia. Over one-third of the labor force earns its livelihood from agriculture, and

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[1]Defined as domestic consumption plus exports relative to beef cattle inventories.

TABLE I

YIELDS OF SOME PRODUCTS IN SELECTED COUNTRIES, 1970 (TONS PER HECTARE)

	USA	USSR	CANADA	JAPAN	MEXICO	ARGENTINA	CHILE	COLOMBIA
Wheat	2.09	1.44	1.79	2.07	2.84	1.25	1.69	1.00
Barley	2.29	1.30	2.23	2.53	1.00	1.05	2.01	1.68
Maize	4.50	2.83	5.29	3.22	--	2.33	3.59	1.25
Rice Paddy	5.12	3.64	--	5.64	2.86	3.99	3.11	2.97
Potatoes	25.60	12.10	19.00	21.30	12.00	12.30	9.10	11.00
Drybeans	1.37	1.67	1.40	1.33	0.59	1.08	1.22	0.57
Sorghum	3.18	1.21	--	1.14	2.50	1.96	--	2.50
Cotton (lint)	0.49	0.85	--	--	0.72	9.32	--	0.61
Milk yield[a]	4154.00	2200.00	3282.00	4330.00	1100.00	1900.00	2860.00	1085.00

[a]Milk yield is per milking cow in kilograms per cow per year. These figures refer to 1969.

Source: FAO Production Yearbook, 1970 and 1971.

unemployment in that sector is a chronic problem.[2] One indicator of economic stagnation is the low rate of change in value of production overtime (Table II), which is different in the agricultural and manufacturing sectors. Absolute levels and differences in the value of output per person per year are shown in Table III, indicating that agriculture indeed lags behind all but one other sector.

TABLE II

COLOMBIA: GROWTH RATES OF VALUE OF PRODUCTION, BY SECTORS (ANNUAL PERCENTAGES)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Agriculture	5.0	3.9	3.2	0.5	--	0.1	3.3	5.1	6.8	3.8
Manufacture	6.1	5.9	6.8	4.7	5.9	4.6	6.6	3.5	6.2	5.8
Total Economy	4.3	5.1	5.4	3.3	6.2	3.6	5.4	4.2	6.1	5.5

Source: Coyuntura Economica, 1969, p. 31

Low agricultural productivity is associated with other chronic problems in Colombian agriculture, including (1) high unit production costs, (2) a large number of small, inefficient farms, (3) inadequate access

[2] In 1971, the employment in agriculture was estimated at about 2.5 million people, which represents 35.7 percent of the labor force in the economy.

to credit and modern inputs, (4) inadequate markets, and (5) unfavorable price relationships between inputs and output. High production costs are a consequence, to a large extent, of inefficiency and low productivity of the sector. Farm size is related to production and productivity levels achieved. Similarly, problems of access to credit and modern inputs, and lack of market incentives will be reflected in the productivity of the sector.

TABLE III

COLOMBIA: AVERAGE LABOR PRODUCTIVITY BY SECTORS, 1970

Sector	Labor Productivity (1958 pesos)
Agriculture	$ 4,148
Mining	12,670
Manufacture	17,247
Craftsmanship	2,809
Construction	4,487
Commerce	10,904
Transportation	14,217
Public Services	18,846
Other Services	6,724

Source: Arango, L. Gilberto. Estructura Economica Colombiana. Bogota, September (1972), p. 139.

The Colombian government is aware of the important role of agricultural productivity in the growth of the farm sector and the whole economy. This awareness is reflected in the new government development plan which includes increasing agricultural productivity as one of the four principal methods of speeding national economic development.[3] However, there is a considerable lack of knowledge concerning agricultural productivity changes in Colombia and about how productivity can be affected through government policies and private action. For example, there is no clear policy on how to encourage farmers to adopt improved technology to raise productivity. Knowledge is lacking also on the expected impact of different production factors and the role of inputs such as research and extension. It is not clear whether crops or animal products should receive top priority in government programs. Similarly, there is no good understanding of how programs for promoting increased production should be organized to assure achievement of established objectives.

Specific examples of policy problems include an "incentive tax" and land reform. The government has attempted to tax the land on the basis of expected yields rather than actual yields so that poor performance becomes penalized. Application of this regulation has called for establishment of minimum land productivity levels. However, this has been an arduous process in Colombia, and the lack of a clear understanding of land, labor and farm inputs and the relationships involved has prevented sound policy formulation. Due primarily to this limitation, implementation of such regulations has been delayed. Only very recently has an attempt been made to implement the law in crop

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[3]The four strategies are: exports, construction, agricultural production and productivity and income distribution. The plan was adopted by the government in December, 1971.

production.

A second example of difficulties encountered in agricultural policy implementation in Colombia is the agrarian reform program, which was designed to raise productivity through more intensive use of land. However, the concentration of land is greater now than when such reform was begun; thus, its major objective has not been achieved.[4]

Objectives of the Study

The principal objective of this study is to determine which variables had the greatest impact on aggregate agricultural output and productivity in Colombia from 1950 to 1971. More specific objectives are as follows:

1. To measure absolute changes and rates of change in the total value of output, and in productivity, for the crop and livestock sectors during the period 1950-1971;
2. To identify and estimate the relative importance of the variables that influenced crop and livestock output and productivity for 1950-1971;
3. To determine if agricultural inputs were employed at their optimum economic levels at the aggregate level;
4. To determine why inefficiencies existed;
5. To formulate aggregate level agricultural policies for future use based upon past experience and potential response in the crop and livestock sectors.

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[4]The Gini coefficient for land concentration in Colombia was 0.861 in 1960 and it declined to 0.813 in 1969. Instituto Interamericano de Ciencias Agricolas y Centro Interamericano de Reforma Agraria, Bogota (1970), p. 63.

Organization of Remainder of Thesis

The remaining chapters of the thesis are organized as follows. Chapter II is devoted to review major concepts and literature related to the study, including Colombia and other countries. Chapter III contains the methodology applied in the study, including discussion of the type of factors considered and the rationale for their inclusion. The models and hypotheses formulated also are presented in Chapter III. The empirical results are presented in Chapter IV for the crop and livestock sectors. The focus is on the sources of growth in the sector making the distinction between sources of production changes and sources of technological change in the case of Colombia's agriculture. Chapter V presents the major policy implications, and finally Chapter VI presents the summary conclusions and recommendations for future research.

CHAPTER II

CONCEPTS AND REVIEW OF LITERATURE

Definition of Terms and Concepts

In this chapter the basic concepts employed are presented, as well as a review of related studies. The terms "productivity change" and "technological change" are frequently used as synonyms, but theoretically they are different concepts. Productivity is a measure of the efficiency with which resources are transformed into goods and services to satisfy wants and needs of consumers. When reference is made to a single input, the output-input ratio is called a partial productivity index; when it is made to all inputs combined, the ratio is referred to as a total factor productivity index. Productivity change is therefore concerned with changes in such ratios.

"Technology" is the body of knowledge that society possesses but does not necessarily use at a given moment of time. This body of knowledge includes that used by industry regarding the principles of physical and social phenomena such as application of genetics to obtain hybrid corn, as well as the relative day-to-day operations of production processes. "Technological change" refers to the adoption of new methods to produce existing products or that make possible the production of products with new and important characteristics. Technological change also may allow firms to create new products, or may result in new techniques of organization, marketing and administration [70, p. 10]. Some authors distinguish between technological and technical change, the first concept being related to progress in the body of knowledge for the whole society and the second being related to the incorporation of new developments to particular economic sectors [85, p. 53]. Except for this distinction, these two concepts are the same and for this reason, they will be treated as synonymous in this study.

The concept of the production function is especially useful in the context of productivity and technological change. A production function refers to a given level of technology. It expresses the physical relationship between a quantity of output and the inputs required to produce it. Use of new technology produces shifts in the production function and these shifts are identified as changes in productivity. Therefore, technological change is the major force underlying productivity change.

According to Brown [17, p. 12], the expression of technological change can be initially visualized through its "abstract qualities" which are characteristics that indicate its nature and effects on changes in production and productivity. Production function analysis can be used to represent these abstract qualities of technological change, which are classified into four categories:[1]

1. the efficiency of the technology;
2. the degree of returns to scale that are technologically determined;
3. the ease with which capital is substituted for labor or vice

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[1]In the present study, only the first two categories will be considered in the further analysis in an explicit way.

versa; and

4. the nature of technological change.

The efficiency of the technology indicates the rate of technological progress and can be graphically represented by successive movements toward the origin over time of an isoquant representing a fixed output. This implies that a given output can be produced in a later time frame with lesser inputs than previously due to the improved efficiency made possible by technology. Total factor productivity is a measure of this concept.

Returns to scale show how production is changed by proportional changes in all inputs. These are indicated by the degree of homogeneity of the production function. If the degree is one, there are constant returns to scale; if it is greater than one, there are increasing returns to scale; if it is less than one, there are decreasing returns to scale.

The ease of substitution between production factors is affected by technological change. The substitution rate corresponds to the slope of the production function and it is measured by the elasticity of substitution. This elasticity measures the degree of response of the ratio of two inputs to proportional changes in the marginal rate of technical substitution between those inputs. Given that the marginal rate of technical substitution is the ratio of the marginal productivities of the inputs under consideration, the elasticity of substitution will measure the extent to which changes in the ratio of marginal productivities affect the ratio of the inputs.

The nature of technological change reflects the degree to which a change in the use of resources leads to a greater (or lesser) saving of a resource relative to another. The effect of the technology in this case may be a greater proportional use of one input and a saving of another input. These changes tend to raise the productivity of one factor over another. For instance, when shifts in the production function result in savings of capital and labor in the same proportion, such technological change is called neutral. When this change results in more saving of labor than that of capital, such an advance is called a labor-saving technological change. Finally, when the bias is toward more saving of capital than that of labor, such an advance is called a capital-saving technological change. These effects of technological change are represented by the production isoquants.

Another way to state the above concept related the marginal rate of substitution.[2] It can be said that a non-neutral technological change alters the production function; the change can be either labor-saving or capital saving. If the marginal physical product of capital rises relative to the marginal physical product of labor for each capital-labor combination, a labor-saving (capital-using) technological change occurs. In this case, there has been a decrease in the marginal rate of technical substitution of capital per labor at every combination of capital and labor. Similarly an increase in the marginal rate of substitution of capital per unit of labor at every capital-labor ratio (combination of capital and labor) results in a capital-saving (labor-using) technological change. On the other hand, a neutral change

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[2] $MRS_{C.N.} = \frac{MP_N}{MP_C}$, where: MRS_{CN} = marginal rate of substitution of capital per labor
MP_N = marginal product of labor
MP_C = marginal product of capital

produces a variation on the production relation itself, but does not affect the marginal rate of substitution of labor per unit of capital.

Variation in the efficiency of a technology and in returns to scale may produce neutral technological change. On the other hand, variations in the capital intensity of a technology and in the ease of substitution may produce non-neutral technological changes. A rise in the capital intensity of a technology produces labor-saving technological change, since such rise increases the marginal product of capital relative to that of labor. A labor-saving (capital-using) technological change is produced in all cases when the technology becomes more capital intensive. On the other hand, an economy where labor grows faster than capital, an increase in the ease of substitution between labor and capital results in a capital-saving (labor-using) technological change. But in an economy in which capital is growing faster than labor, an increase in the ease of substitution (elasticity of substitution) increases the marginal physical product of capital relative to that of labor and therefore a labor-saving technological change has taken place [17, p. 22-26].

The economic rationale of these relationships may be explained as follows. When capital is growing relative to labor, capital becomes the relatively cheap factor, and the technological advance which eases the substitution of the relatively cheap capital for the relatively expensive labor must certainly be labor-saving. Similarly if labor is growing relative to capital, labor becomes the relatively cheap factor, and the technological advance which facilitates the substitution between labor and capital is capital-saving (since capital would be the relatively expensive factor).

Alternative Production Functions and Their Uses

The literature on the use of production function analysis applied to productivity and technological change is vast.[3] The Cobb-Douglas function is the most popular form for it has proven to be useful and convenient for empirical work. Its form is:

$$Y = AN^{\alpha} C^{\beta} \qquad (1)$$

where

Y = output

N = labor input

C = capital input

A, α, β = constants

For productivity analysis, the Cobb-Douglas function must meet certain requirements: the marginal products are positive; over a relevant range, each marginal product should decrease; and the function does not specify a priori the degree of economies of scale. The marginal products are:

$$MP_N = \frac{\partial Y}{\partial N} = \alpha\frac{Y}{N}$$

$$MP_C = \frac{\partial Y}{\partial C} = \beta\frac{Y}{C}$$

The following may be derived:

$$\alpha = \frac{\frac{\partial Y}{\partial N}}{\frac{Y}{N}} = \text{elasticity of output with respect to labor}$$

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[3]For an excellent survey see Walters, A. A. "Production and Cost Functions: An Econometric Survey." Econometrica, Vol. 31, No. 1-2 (January-April, 1963), pp. 1-66. For a review on the field of applied econometrics see Bridge, T. L. Applied Econometrics. North-Holland Publishing Company, Amsterdam (1971), pp. 321-397.

$$\beta = \frac{\frac{\partial Y}{\partial C}}{\frac{Y}{C}} = \text{elasticity of output with respect to capital}$$

Now, ($\propto$ + β) measures the degree of homogeneity of the production function, i.e., the returns to scale. For the Cobb-Douglas function, the marginal rate of substitution of labor per unit of capital, $MRS_{N,C}$ is given by:

$$MRS_{N,C} = \frac{MP_C}{MP_N} = \frac{\beta\frac{Y}{C}}{\propto\frac{Y}{N}} = \frac{\beta}{\propto}\ \frac{N}{C} \tag{2}$$

Also, the elasticity of substitution is given by:

$$\sigma = \frac{\frac{\Delta\frac{N}{C}}{\frac{N}{C}}}{\frac{\Delta MRS}{MRS}} = \frac{\frac{\Delta\frac{N}{C}}{\frac{N}{C}}}{\frac{\frac{\beta}{\propto}\Delta\frac{N}{C}}{\frac{\beta}{\propto}\ \frac{N}{C}}} = 1 \tag{3}$$

For the Cobb-Douglas function, the elasticity of substitution is always unitary. From (1) it can be seen that:

$$\frac{\partial Y}{\partial A} = N^{\alpha}C^{\beta} = \frac{Y}{A} \tag{4}$$

which implies that a proportional change in A produces a proportional change in output, other things being constant. A is called the coefficient of efficiency.

The degree of factor intensity can be represented by a variation in the ratio of the elasticities of output, that is, variations in the ratio of β to $\propto$. If β rises relative to $\propto$, then a capital intensive technique is being used. From (2) it can be seen that the marginal product of capital has risen relative to that of labor at each labor-capital ratio. Thus, the Cobb-Douglas function provides representation for three out of the four abstract qualities of a technology. Only the degree of substitutability presents a limitation in this case.

The Cobb-Douglas function has been extensively used since the early formulation by Professor Douglas [27] in which he provides estimates for the United States for the period 1899-1922. Douglas' main contribution was the development of this type of function and the first empirical work using such a specification. The function has been used thereafter in many situations to analyze productivity and returns to resources both at the micro and macro level. One of the first econometric formulations of technical change using the Cobb-Douglas function was made by assuming that neutral technical change takes place as a smooth function of time. This formulation implies an exponential form, represented by:

$$Y = AN^{\alpha}C^{\beta}e^{\lambda t} \qquad (5)$$

where

e = basis of natural logarithms

λ = rate of technical change

t = trend variable, i.e. time

Brown [17, pp. 148-164] attempted to measure technical progress in the United States by "epochs." A "technological epoch" corresponds to a time period within which the production function has remained stable. The operational procedure for identifying each epoch consists of applying stability analysis to estimates of the production function. For this procedure, it is assumed that the ruling technology embodied in the existing production function becomes more efficient through time in a neutral way. Once a non-neutral change occurs, we pass to a different technological epoch. The function is fitted in its first difference form given by:

$$\Delta Log\ Y = \Delta Log\ A + \propto \Delta Log\ N + \beta \Delta Log\ C$$

Solow's approach [84] to technical progress is different from Brown. Using a form

$$Y = A_{(t)}\ C^{\beta}\ N^{1-\beta} \qquad (6)$$

expressed on a per unit of labor basis, this can be written as

$$\frac{Y}{L} = A_t \left(\frac{C}{N}\right)^{\beta}$$

From the above, we can obtain

$$\frac{\Delta \frac{Y}{L}}{\frac{Y}{L}} = \frac{\Delta A_t}{A_t} + \beta \frac{\Delta \frac{C}{N}}{\frac{C}{N}} \qquad (7)$$

Using the estimate of β as the share of property income in non-material income enables the generation of a series for $\Delta A_t/A_t$ and further a series for A_t, the measure for the index of technological change. This index will measure neutral technological changes since only changes in the efficiency parameter are considered.

Arrow, Chenery, Minhas and Solow [4] derived the so-called constant elasticity of substitution function (CES) which includes as special cases: (1) the Leontief or fixed coefficient function; (2) the linear and homogenous function; and (3) the Cobb-Douglas function. For the CES function, the elasticity of substitution is constant but not necessarily zero or infinity. It still has the restriction that the value of the elasticity of substitution is constant and independent of the capital-labor ratio. Besides experience has shown that data are relatively difficult to fit with the CES function [17, p. 61]. The CES function has been used in several studies mainly in the United States [19, 67, 71]. Due to difficulties in fitting the function a one-side relationship, in this functional context, has been used more recently [44, 65] which allows estimation of some of the parameters specified in the model. For developing countries, one of the few studies reported is Katz' study [65] on the Argentine manufacturing sector for the period, 1946-1961, with very useful results.[4]

Lu and Fletcher [68] derived the variable elasticity of substitution function (VES) which includes most known forms of production functions as special cases. Here, the elasticity of substitution is not required to be constant, but is a function of the capital-labor ratio. However, this function has the disadvantages that it is more complex and time consuming to estimate. Also, the VES and CES functions are difficult to generalize for more than two inputs.

In summary, only the Cobb-Douglas and the CES functions with some extensions have been used in empirical work using aggregate data with relative success. For this reason, for productivity and technological progress analysis, the range of production functions is practically limited to those two functions.

Studies Using Production Functions and Indexes

Several research studies on production and productivity have derived various techniques for measurement in the agricultural sector. Kendrick [66] used an arithmetic index to estimate the rate of increase in total factor productivity in the American economy for the 1899-1957

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[4]For a survey, see Nerlove, Marc. "Recent Empirical Studies of the CES and Related Production Functions," in Brown, Murray, ed. "The Theory and Empirical Analysis of Production." Studies in Income and Wealth, Vol. 31, National Bureau of Economic Research, Columbia University Press (New York, 1967), pp. 55-122.

period. The U.S. Department of Agriculture also used an index to estimate the productivity of agriculture. In that index, inputs are combined arithmetically with factor-prices as weights.[5] Solow [84] on the other hand, used a geometric index in the study on technological change of the American economy for the 1909-1949 period.[6]

Nevel [78] also used Solow's approach with some modifications in the study of technological change in American Agriculture for the 1950-1966 period. In this case, the inputs were geometrically combined and relative factor shares were used as weights. Nevel defined capital to include three separate categories: (a) land, buildings, livestock and other inventories, (b) farm machinery and equipment, and (c) intermediate purchased products used in production for a single year, i.e., feed, fertilizer, seed, etc.

Denison [30], made a comparison of the growth rates of national income in nine western countries and the United States. His major objective was to identify the main sources of growth in each of these countries in a broad category of sources. He also attempted to explain the relative importance of these sources of growth between those countries and the U.S.A. Denison distinguishes between sources associated with inputs and other sources that cause changes in the output-input ratio. The resources are classified into labor, capital and land, the first two being classified into internal categories according to

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[5]It assumes that inputs are associated in a sum form in a context of production $(X_1 + X_2)$.

[6]It assumes that inputs are associated in a multiplication form $(X_1 \cdot X_2)$.

data availability. An important contribution of Denison's work was the estimation of the contribution of changes in hours worked, education of the labor force, and related movements. Denison's classification includes 22 sources, nine related to resources and 13 related to the output-input ratio. His method is a factor share approach and a total factor productivity approach to estimate the contribution of each factor and each category of the factors considered. The contributions of total factor input and the output-input ratio are also calculated, the latter being calculated as a residual.

Ruttan and Hayami [83] in a more recent study placed emphasis on the technology transfer on an international basis. Their analysis placed special emphasis on the emergence of a national experiment station's capacity to conduct and adapt research in the developing countries. They pointed out that the most serious constraints on the international transfer of agricultural technology are: (a) limited experiment station capacity to employ biological technology and (b) limited industrial capacity to absorb mechanical technology, while the inelastic supply of scientific and technical manpower represents a critical limiting factor on both cases. Ruttan and Hayami reached the conclusion that the key to a successful international transfer of agricultural technology is the modification in the design and use of machines, chemicals and production techniques, to conform with factor endowments and relative factor prices in particular countries. Ruttan and Hayami stressed the importance of institutional aspects involved in the international transfer of technology. They visualize the new international agricultural research centers that have been recently established and associated with the so-called "green revolution" as an effective institutional basis to make possible an increased diffusion.

In other research works, Hayami and Ruttan [52, 53] studied the sources of productivity differences among countries. They made comparisons between the United States and Japan and between Japan and India. They concluded that among the most significant sources are resource endowments, technical inputs and human capital, the latter being related specifically to scientific and technical manpower availability. They consider capacity transfer, in which scientific knowledge is transferred, to be the last phase of international technology transfer.

Two significant conclusions in an earlier study by Hayami [51] were (1) that differences in the inputs of modern man-made factors account more for the difference in productivity than differences in the endowment of original factors and (2) that education and research are crucial in closing the productivity gap. For less developed countries, the major implication of these studies by Hayami and Ruttan is the importance of experiment stations and maintenance of international research centers in order to bring about easier and cheaper ways of adapting technology and obtain significant advances in agricultural productivity.

In a study conducted by Hertford [55] on Mexico's Agriculture, the agricultural development process in that country was described and the major sources of increased production and productivity were identified for the period 1940-1965. The method used was a total factor productivity approach. Furthermore, the use of production function analysis allowed determination of the effects of tenure and irrigation on productivity and some comparisons among productivities of inputs. The production function model was the Cobb-Douglas function. Hertford's approach, using the factor share method in the first part of the analysis and then the production function analysis appears to be appropriate in this case, since one method is complementary to another. However, factor shares used are referred to a given year, i.e., 1960 which could introduce a certain bias in the analysis. One alternative is to use the average factor shares for each of the subperiods considered and for the whole period separately. This is the approach used by Katz [65] in his study on growth of the Argentine manufacturing sector. However, if the factor shares are relatively stable through time, the results will not change by the use of either method.

In Colombia, partial productivity indexes have been used in analyzing the agricultural sector. Atkinson [6] compiled a series of production figures for various crops for the 1948-1968 period and includes the following products:

Group 1 -- Coffee

Group 2 -- Cassava, dry beans, plantains, non-centrifugal sugar

Group 3 -- Corn, potatoes, wheat, tobacco

Group 4 -- Banana, cocoa

Group 5 -- Cotton-fiber, cottonseed, rice, sugar

Group 5A-- Sesame, barley, soybeans, sorghum

The above classification is based mainly on the state of the technology used in production. Group one corresponds to coffee, the major crop cultivated in Colombia. Group two corresponds to traditional crops. Group three includes crops with mixed technology that utilizes traditional and non-traditional methods. Group four contains plantation crops which are of relatively little importance in the country and group five are the principal mechanized crops. Group five A corresponds to other mechanized crops, some of which are relatively new, but of increasing importance. Atkinson indicated that over the twenty-year period analyzed there generally was very limited technological advance in crop production. The author also indicates that there is some evidence that the restriction on imports of non-traditional inputs (mainly fertilizer and chemicals) only partly offset by domestic production, had been a serious constraint on improving technology [6, p. 20].

Some articles have been written with reference to productivity of the Colombian farm sector. Among these, Cardona [22] made an overall analysis for crops and cattle. He attempted to evaluate the present state of those sectors and mentioned some technical problems that these sectors face as well as what might appear as the most immediate causes. Cardona stated that one of the most crucial problems of Colombian agriculture is the diffusion and adoption of new technologies at the farm level, especially at the small-size farmer level. Cardona argued for the need to introduce technological changes in the sector as a basic step toward an improving productivity.

Luna and Hildebrand [69] studied the productivity of resources in zones of "minifundio" (small-size holdings). They found under-utilization of labor in preparing the land, and low efficiency of the implements used. The authors point out that there is a tendency to use excessive quantitites of labor in the other cultivation activities [69, p. 343]. They concluded that the solutions to the problem of low productivity should be directed primarily to changes in small farm technology. This study is limited to the productivity of specific resources, such as land and fertilizers, particularly marginal productivities in the case of the elected region (Municipio de Yacuanquer, State of Nariño).

Two more recent studies in Colombia dealt with the subject of productivity in a more specific way. One of these was a study conducted by Atkinson [7] on changes in productivity and technology. Atkinson found that agricultural productivity in Colombia, i.e., total production per unit of input, increased at an annual rate of 1.6 percent during the 1950-1967 period, and total agricultural production increased at an approximate annual rate of 3.0 percent. Production per capita, in turn increased at an annual rate of 2.0 percent during the same period. Atkinson studied different groups of crops and noted production of major crops grew at a rate of 3.15 percent annually. According to the study, one-half of this growth can be attributed to an increased land use and the remaining growth to greater yields. He concluded that progress in agriculture has been uneven, with good gains for crops such as cotton, rice, sugar cane and poultry, and that most of the increase in crop production was associated with mechanization of relatively large farms located in fertile valleys. This situation contrasts with that of small farmers who face a series of obstacles besides the limitation on size of farm, which constrain expansion and modernization through the use of non-traditional inputs [7, p. vi]. It was shown that there has been a relative decrease in the share of traditional small farmer production in total production for the period considered.

Atkinson derived estimates of total factor productivity for the years 1950, 1958 and 1967. He attempted to explain the progress that had taken place in Colombian agriculture in the 1950-1967 period, including the characteristics of the expansion. The possibility of obtaining indexes of total factor productivity of all the years was not considered. Neither physical nor non-physical sources of production and productivity change were identified due to the focus of the study. In fact, the study was more concerned with measures than explanation of changes that occurred in production. The lack of a systematic approach in conducting the analysis prevented more meaningful and useful results.

The second recent study is by Berry [13], who conducted a study on income distribution and efficiency of Colombian agriculture. He concluded that the growth of agricultural production until about 1950 was explained mostly by the growth of traditional inputs, i.e., that the growth in total factor productivity was of little importance. On the other hand, from 1950 on, technological change became more important. Berry presented some calculations which showed that production (value added) per hectare and per peso of capital (including land) decreased as the size of farm increased, while production per person increased. Berry also calculated some production efficiency indices as value added divided by the value of the factors used, measured by their social opportunity cost. He concluded that the smallest farms (0-3 hectares) were the least efficient, but that the other groups were near the average, with some indication that those in the range of 5-50 hectares and especially those in the range of 5-10 hectares were the most efficient [13, p. 45]. These estimates referred to 1960. They were based on the implicit assumption that capital and labor are homogenous factors for all farm sizes. By some adjustments, Berry restated his conclusion by noting that there is greater efficiency on smaller size farms (5-10 hectares), compared to larger farms. He pointed out that the major factor explaining the greater value-added per value of scarce resources (land and capital) on small farms appears to be the different proportions of the land devoted to crop and cattle activities. The conclusion was difficult to demonstrate statistically due to the apparent differences in land quality for the different farm sizes [13, p. 55]. Berry did not attempt to compare his 1960 data with those of the last four or five years. Berry assumed that the dynamism of Colombian agriculture was very limited and that the present basic situation tends to remain.[7]

The Cobb-Douglas function has been used in some studies in Colombia. One study by Bostwick [15] in the Cauca-Valley on analysis of organization of farms in the region related to use and productivity of inputs used this function with meaningful and useful results. Another study by Rojas [82] in the same region also produced satisfactory results. These studies undertaken in Colombia have proven the Cobb-Doublas function to be a useful analytical device for production economics research in the country. However, there have been no previous aggregate level studies in Colombia applying the Cobb-Douglas function using either cross section data or time series data. The main gap in the studies undertaken in Colombia is that they have not identified the sources of growth, they have not determined the contribution of inputs to growth in agriculture, and they have not measured systematically productivity of inputs or total factor productivity through time. There was a study underway by Kalmanovitz [64] at the time this study was being undertaken but only the first part was available. Kalmanovitz made basically a

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[7]Berry needed to use census data since his focus was efficiency for different farm sizes. After 1960, the next census was conducted in 1970, and this prevented such type of comparisons by that time.

historical review of Colombia's agriculture with some important economic considerations mainly on the use of labor and capital in the sector and the behavior of labor wages. The descriptive approach used in that study, precludes comparison with some other studies in which specific economic analysis is carried out.

Contribution of This Thesis

The present study will focus on the Colombian farm sector, analyzing production and productivity changes to determine the sources of such changes. The analysis will be made separately for crops and animal products in order to compare the two agricultural sectors. The research will build further on several aspects mentioned in some of the previous studies cited, mainly on production and productivity changes and the forces underlying such changes. In this study, total factor productivity estimates and partial productivity estimates will be developed. Further, an attempt to explain the corresponding productivity changes will be made. These new dimensions of Colombia's agriculture, together with the use of production function analysis will be used to estimate elasticities of production for several factors, the degree of returns to scale, economic efficiency, and contributions of several inputs to production.

Some new specific aspects included in this research are: (1) the analysis of the crop and livestock sectors in aggregate terms with focus on sources of growth and economic efficiency in the use of resources; (2) the incorporation in an analytical framework of nonconventional factors such as research and extension, credit, and education, and (3) the magnitudes and relative importance of the conventional factors such as land, labor, power and purchased inputs involved in changes in production and productivity in Colombia's agriculture. Providing this information should help build a better understanding of the economic and technical conditions in which agriculture operates.

The analysis will make possible the identification of the major sources of growth in the farm sector, making the distinction between physical sources and non-physical sources, the determination of contribution of inputs to growth and the measurement of total factor productivity for the period analyzed. The framework to be used will allow the identification of the opportunities that Colombia's agriculture faces for larger and sustained increases in production and productivity.

The results of this study will constitute new quantitative information for the aggregate Colombian agriculture or the crops and the livestock sector concerning input-output relationships and their relevance. Furthermore, the knowledge acquired through the study and its implications will provide sound basis for policy decision makers concerning measures aimed at increasing productivity and technological change in agriculture.

CHAPTER III

METHODOLOGY

Introduction

As documented in Chapter I, agricultural productivity in Colombia has been low and the performance of the sector must be improved if the increasing needs for food and fiber in the economy are to be fully satisfied. It is also recognized that a lagging agricultural sector is a problem for the whole economy. Colombia as a developing country must accelerate the progress of its agricultural development if that sector is to play an important role in the economic development of the nation. Low agricultural productivity in general is a serious constraint to the industrialization and economic growth of developing countries. The above considerations lead us to the question: What are the sources of production movements and productivity growth in Colombia's agriculture? To answer this question, a distinction is made here between physical sources and non-physical sources.

Physical sources are related to the inputs directly involved in the productive process such as land and labor. Non-physical sources are factors that may affect the rate of technological change and further productivity gains through the improvement of conditions involved in the production process. These factors are sources of technological change as a major force behind productivity growth. The first category of sources is composed of traditional or conventional inputs, while the second category is composed of so-called non-traditional or non-conventional inputs such as research, extension, and education. To explore in a systematic way the answer to the above question, several hypotheses are formulated on the basis of the knowledge accumulated about the conditions and performance of Colombia's agriculture. The major criterion for the formulation of hypotheses in this case is that they are testable using the data employed in the study.

The hypotheses formulated are:

1. In an economic sense, land tends to be overemployed in livestock production, and transfer of land from livestock production to crop production will result in a greater value of output.
2. Land productivity is influenced mostly by the use of power in the crop sector and by the use of animal inventories in the livestock sector.
3. Intermediate purchased inputs are important in inducing output growth in both subsectors as indicated by large output gains from additional increases in the inputs.
4. Productivity of the whole agricultural sector in Colombia is low, due to the relatively small change in the structure of input utilization and constraints faced by producers for an expanded use of these inputs. Furthermore, there is a limited amount of use of certain non-traditional inputs such as research and extension and credit, which affect significantly productivity growth.
5. The crop sector exhibits increasing returns to scale given low levels of input use relative to input marginal productivities.

6. The livestock sector has had lower average land productivity than the crop sector but livestock production benefits greatly from increasing returns to scale.

Hypotheses (1) and (2) can be considered as _a priori_ under the current conditions in Colombia's agriculture. Hypotheses (5) and (6) are also _a priori_ statements in the sense that they appear to be rational for a developing country which faces considerable economic opportunities for growth. However, in the case of all the hypotheses stated above, the important need is for a quantification of the elements involved so that they can be used as information on which to base policy decisions.

In considering the factors involved in the above hypotheses and to analyze sources of production and productivity changes, two approaches prove to be useful: the factor share and the production function approach. The factor share approach is used as a first method in the inquiry of technological change and sources of production changes. The basic method and results are reported in Appendix A. The factor share approach also proves to be useful as a background to the application of the second method, the production function approach. This latter method is discussed at length in this chapter.

The Production Function Approach

The production function approach is a more systematic method of analysis than the factor share approach and will be employed in the present study. The model of production function used is the Cobb-Douglas function. This model is chosen for three major reasons:

1. Estimation of Cobb-Douglas type functions allows the use of

elasticity estimates which are not necessarily factor shares, but those obtained properly from the data;

2. The Cobb-Douglas function assumes unitary elasticity of substitution such that income shares of capital and labor remain constant for any changes in the relative supply of capital and labor.

Let us consider the function, $Y = AN^{\alpha}C^{\beta}$ where

Y = output

N = labor input

C = capital input

In equilibrium we have:

$$MRS_{n,c} = \frac{MP_c}{MP_n} = \frac{i}{w} \qquad (1)$$

$$\frac{\beta}{\alpha}\frac{N}{C} = \frac{i}{w}$$

$$\frac{\beta}{\alpha} = \frac{iC}{wN} = \text{capital's relative share of income} \qquad (2)$$

where:

i = rental price for capital (interest rate)

w = wage rate

Expression (2) is constant for any period analyzed and the underlying technology since β and α are constants.

In Colombia, the crop sector's labor share declined from 40 percent to about 31 percent during the period 1950-1958, and from 29 percent to 27 percent during the period 1959-1971. For livestock, labor's share has had smaller fluctuations with an average value of 15 percent during 1950's and 12 percent during 1960's. For the whole sector labor's share fluctuated between 26 percent and 22 percent for the period 1950-

1971. These data suggest that the labor's share has not fluctuated much through time and that for certain periods tends to be relatively constant. This pattern of factors' shares justifies to a certain extent the use of the Cobb-Douglas function. Moreover, the actual estimates of the elasticity of substitution support the use of the Cobb-Douglas function, with more statistical support in the case of crop production.[1]

3. The Cobb-Douglas function has proven to be useful as an analytical device in prior research experience in Colombia.[2] The function is also chosen due to the ease and convenience of manipulation.

In Colombia, the crop and livestock sectors are markedly different. The two sub-sectors do not show a significant degree of complementarity; whereas in most countries, the crop and livestock sectors do tend to be complementary [64]. Different forces have had an influence in each sector, and the crop and livestock sectors have different patterns of development. For these reasons and to provide a better insight in each case, the analysis is conducted separately for crops and livestock. Also, the analysis conducted in this manner will allow direct comparisons. Furthermore, it will be possible to make inferences concerning

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[1]The CES model developed in several studies [44, 65] was employed here, $\log y = a + \hat{\delta} \log w + ct + u$ where: y = value added per man-year; $\hat{\delta}$ = elasticity of substitution estimate; w = wages per man-year; and t = time. The values for the elasticity of subsitution estimate were 0.80 for crops, statistically non-different than one, so that it is in the range $0 < \hat{\delta} \leq 1$ and for livestock, the value obtained was 0.50, and statistically in the range $0 \leq \hat{\delta} < 1$.

[2]See Chapter II in this thesis, p. 26.

the most important policy implications for each sector.

The Models

To have a satisfactory expression for the relationships to be estimated, in both an economic and statistical sense a relevant set of explanatory variables should be included in the model. In this context two general hypotheses are formulated, one for each subsector as follows:

1. Intermediate purchased inputs, land, power and labor have a functional relationship to crop output and provide a good statistical fit for the aggregate crop production function. Intermediate inputs include seeds, fertilizers and chemicals. These inputs, along with the other conventional inputs, are the major categories of factors employed in crop production in Colombia. In this sense, the statement is an a priori hypothesis; the test is the statistical estimation.
2. Concentrates, pasture land, animal inventories, labor and power explain the variation in livestock output. Concentrates are the most important intermediate purchased input employed in livestock production, and in that sense can be interpreted as a proxy to this whole category of inputs. As in the case of crops, the above statement is an a priori hypothesis, for these factors are the major categories of inputs employed in livestock production.

In the group of non-conventional inputs, primary factors that are expected to have a direct association with output and productivity levels are research and extension. These activities are intended to raise farm production and productivity and to enable farmers to use new and improved technology. Griliches [50] used the research and extension variable in the fit of the aggregate agricultural production function for the United States. He found the contribution of that variable highly relevant. In Colombia, Ardila [3] and Trujillo [86] found that research expenditures for rice and wheat have been highly profitable with high internal rates of return. In the present study, it is hypothesized that research and extension are relevant in influencing output and productivity in Colombia's agriculture and will be included in the models to be estimated.

Concerning other non-conventional inputs, the most relevant factors are quantified and included in the model to explain total productivity in Colombia's agriculture. The rationale for the inclusion of such variables is discussed in the specification of that model later on in this chapter.

The Model for Crops

This model is specified as follows:

$$Y = A\, X_1^{\beta_1}\, X_2^{\beta_2}\, X_3^{\beta_3}\, X_4^{\beta_4}\, X_5^{\beta_5}\, e^{\varepsilon} \qquad (3)$$

Expressed in logarithms the equation is

$$\log Y = \log A + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + e$$

where:

Y = value of output in millions of 1958 pesos;

X_1 = intermediate purchased inputs (seeds, fertilizers and pesticides) measured in index form;

X_2 = land measured as hectares of cropped land;

X_3 = power measured as interest on investment in machinery and draft animal investment in crop production;

X_4 = labor, measured as the number of man days employed in crop farming;

X_5 = research and extension, measured as government expenditures on these programs; and

ε = error term, subject to standard assumptions, i.e., mean zero and variance, σ^2.

The model specified in (3) is a multiplicative non-restrictive model of the Cobb-Douglas production function. Such specification implies that the output is log-normal distributed i.e., skewed with respect to X_1, X_2, X_3, X_4 and X_5.

<u>The Model for Livestock</u>

This model is specified as follows:

$$Y = A_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} e^{\varepsilon} \quad (4)$$

where:

Y = livestock output, valued in millions of 1958 pesos;

X_1 = concentrates consumed, measured in tons;

X_2 = land, measured as hectares of pasture land;

X_3 = livestock capital, measured as interest on livestock inventories in millions of 1958 pesos;

X_4 = labor, measured as the number of man-days employed in livestock farming,

X_5 = power, measured as interest on investment on machinery and draft animal investment in livestock production;

X_6 = research and extension, measured as government expenditures on these programs; and

ε = error term, subject to standard assumptions.

Further Uses of the Models

All of the above models can be estimated by ordinary least squares since they are linear in the logarithms of the variables. The research-extension variable is introduced in both current values and lagged values to gain further insight on its relevance. The elasticity estimates are used to develop an accounting formula to explain the variation in output as explained by each input. For some models the equation fitted is the first difference form of the Cobb-Douglas function.

$$\Delta \log Y = \alpha + \sum_{i=1}^{n} b_i \, \Delta \log X_i \qquad (5)$$

For continuous changes we have:

$$\frac{d(\log Y)}{dY} = \frac{1}{Y}$$

and relating changes in differential form:

$$d(\log Y) = \frac{1}{Y}(dY)$$

For discrete changes, we can write:

$$\Delta(\log Y) = \frac{1}{Y}(\Delta Y)$$

where the Δ's represent the changes between consecutive time periods as approximations to the derivatives. Similarly for X_i, we obtain:

$$\Delta \log X_i = \frac{1}{X_i}(\Delta X_i) \qquad (6)$$

Now, equation (5) can be written as:

$$\frac{1}{Y}\,\Delta Y = \alpha + \sum_{i=1}^{n} b_i \frac{1}{X_i}\,\Delta X_i \qquad (7)$$

When first differences are not used, α is the usual regression constant. In the first differences form α is the trend coefficient which allows for shifts in the production function. From equation (7), both the change in output associated with the change in each input, and the change associated with the combined inputs can be calculated. In (7), $\frac{1}{Y}\,\Delta Y$ and $\frac{1}{X}\,\Delta X$ are the percentage changes in output and input respectively. The accounting formula used is explained in each case in the course of the analysis.

In cases where the statistical tests indicate that the estimated function exhibits constant returns to scale, i.e., is homogenous of degree one, it is useful to apply Nevel's method [78] to gain some further insight on sources of labor productivity growth. The objective is to determine the contribution of technological change to such growth. Under the assumption that factors are paid their marginal products and that the change is of the neutral type, the production function can be written as

$$Q = A(t)\; N^{1-\beta}\; C^{\beta} \qquad (8)$$

where

Q = output;

N = labor input;

C = capital input; and

β = elasticity of output with respect to capital.

Dividing by N

$$\frac{Q}{N} = A(t)\; N^{1-\beta-1}\; C^{\beta} = A(t)\left(\frac{C}{N}\right)^{\beta} \qquad (9)$$

To express changes, equation (9) can be written:

$$\Delta \log \frac{Q}{N} = \frac{\Delta At}{At} + \beta \, \Delta \log \left(\frac{C}{N}\right) \tag{10}$$

where Δ's stand for the difference between consecutive periods. To illustrate with the case of crops, the values of the capital input (C) refer to purchased inputs (I), power (P) and land (L), so we can write:

$$\Delta \log \frac{Q}{N} = \frac{\Delta At}{At} + \beta_1 \, \Delta \log \frac{I}{N} + \beta_2 \, \Delta \log \frac{P}{N} + \beta_3 \, \Delta \log \frac{L}{N} \tag{11}$$

The differences in logarithms can be expressed as a percentage of change in the original variables. Then we can write

$$\frac{\Delta \frac{Q}{N}}{\frac{Q}{N}} = \frac{\Delta At}{At} + \beta_1 \frac{\Delta \frac{I}{N}}{\frac{I}{N}} + \beta_2 \frac{\Delta \frac{P}{N}}{\frac{P}{N}} + \beta_3 \frac{\Delta \frac{L}{N}}{\frac{L}{N}} \tag{12}$$

where, purchased inputs, power and land are expressed per unit of labor. Then,

$$\begin{aligned} \frac{Q}{N} &= q \\ \frac{I}{N} &= i \\ \frac{P}{N} &= p \\ \frac{L}{N} &= l \end{aligned} \tag{13}$$

Using the elasticities estimates obtained for the β's, then

$$\frac{\Delta q}{q} = \frac{\Delta A}{A} + \hat{\beta}_1 \frac{\Delta i}{i} + \hat{\beta}_2 \frac{\Delta p}{p} + \hat{\beta}_3 \frac{\Delta l}{l} \tag{14}$$

The above procedure allows the determination of the contribution of inputs and technological change to productivity. The latter is indicated by the value $\frac{\Delta A}{A}$ in (14).

The Model for Total Productivity:

Nonconventional Inputs

This model is applied to the whole sector with the purpose of identifying the relevant factors associated with technological change in Colombia's agriculture.[3] The total productivity index is an expression of the aggregate output-input ratio. In this index, the aggregate inputs labor and capital are weighted by the factor shares in a base period. Since the index is designed to measure efficiency gains in production, it is often taken as a proxy for technological change [70, p. 10].

The total productivity index expresses output per unit of labor and capital combined. In this sense it is an indicator of the efficiency with which both labor and capital together are used in the production process. The total productivity index is estimated with the inputs aggregated and weighted by relative factor shares.[4] Labor and capital are weighted by the factor shares in the base period. The base period initially selected is 1958.[5] However, the base period is shifted to 1950 to present a clear picture of productivity growth through time, given that 1950 is the initial year in the series. The formulation

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[3]The available data for variables considered in this case prevents the application to crops and livestock separately. Also, some of those variables such as education and weather are difficult or impossible to separate between individual sectors. Consequently, this analysis will be made for the whole sector in which livestock and crop sectors are included.

[4]The weights commonly used are the factor prices or the factor shares in certain selected periods. The geometric index implies a Cobb-Douglas production function while the arithmetic index with factor prices as weights implies a homogeneous and linear production function.

[5]The year 1958 is selected as a basis to facilitate comparisons with other economic indexes which are commonly presented on that basis in national accounts in Colombia.

used for the total productivity index is as follows:[6]

$$TPI = \frac{Y}{\alpha N + \beta C} \qquad (15)$$

where:

TPI = total productivity index;

Y = output, as a percent of output in 1958;

N = labor input as a percent of labor input in 1958, with original data expressed in number of man-days employed in agriculture; and

C = capital input as a percent of capital input in 1958 with original data expressed in 1958 pesos.

It is important to identify the sources associated with total productivity in agriculture in an attempt to determine non-physical sources of growth. In the definition of the index, the conventional inputs are considered to be the aggregate labor and capital inputs. Thus, the explanatory variables of total productivity change should be other non-conventional factors that influence the efficiency in use of resources and total efficiency in agricultural production. That is, the factors to be related to total productivity as a proxy for technological change should be different from the conventional inputs, since the aim is to identify non-physical sources.

The underlying hypothesis here is that there are some factors that bring about efficiency gains in Colombia's agriculture through shifts in the aggregate agricultural production function, namely the non-

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[6]This formula was first developed by Domar [40] and is also explained in Mansfield [70].

conventional inputs such as research, extension, and education. These shifts are associated with increases in the output-input ratio, that is, with productivity increases for the whole agricultural sector. These factors are thought to influence agricultural production efficiency through improvements in certain conditions such as availability of improved technology, ease and stimuli for adoption of technology, management skills, etc. The factors that are involved in this process are sources of technological change.

The determination and measurement of these sources has had a slow development in economic literature. The major weakness is lack of a suitable theory to be used as a framework. This is perhaps the major difficulty concerning the analysis of productivity and technological change. Blaug [14, p. 472] concludes that "indeed, it is fair to say that contemporary economics lacks a systematic theory accounting for the rate and slant of innovations over time, and this failure to provide an explanation of the origin and nature of technical change probably constitutes the most important defficiency in current theorizing on economic growth." However, it is possible to rationalize on this subject for the Colombian case, based on some knowledge obtained both in the country and other countries.

One factor that can be included in the explanation of total productivity is the research and extension program. In general, it is expected that the amount and quality of resources devoted to the improvement of an industry's technology will have a large effect on the rate of technological change in that industry. In agriculture, the creation of improved technology takes place through research programs, generally undertaken by the government in universities and agricultural experiment stations. Extension activities complement research through diffusion of technology. Griliches [50] used government expenditures on research and extension as a variable to estimate its effect on U.S. agricultural output. Similarly, Burnham, Quance and Howell [20] regressed in log form for the period, 1957-1970, the lagged values of agricultural research and extension and the USDA productivity index for agriculture. Their aim was to estimate the impact of research expenditures on agricultural production efficiency. In Colombia, Ardila [3], Trujillo [86], Hertford [54] among others have found a high internal rate of return to research programs in various crop products. The experience gained from the above studies indicates that research and extension is a relevant variable to associate with productivity growth in agriculture.

The technical assistance provided to farm producers will enable them to be aware of new techniques. In Colombia, the technical assistance programs were one of the first government efforts organized through special campaigns for improvement of agricultural production. These activities may speed up the adoption of farm technology and may be associated with productivity in the sector. Thus, technical assistance is a second variable analyzed in the model.

Another variable that has been considered in several studies to be closely related to technological change and productivity is demand for the final product. The expected relevance of demand for the final product as a source of technological change is described by Quinn [81 , p. 91] as follows

> In fact a technology is utilized only if it responds to a need. Otherwise it remains a capacity and never becomes a functioning reality ... If an anticipated demand is strong

> enough, it will generally call forth the human and physical resources necessary to attack its technological problems. Once stimulated and adequately supported, human imagination is likely to solve those problems unless prevented by physical laws or by institutional barriers. And even institutions may change if demand is strong enough.

The demand for farm products is an indicator of the market size which is expected to influence productivity of the sector. Agriculture, as any other economic activity, depends upon demand for its progress. The stronger the demand for farm products, the stronger the incentive to increase productivity so as to have increased production from a given set of resources to meet the demand. Then, the relevant variable from this viewpoint is the level of aggregate demand for agricultural products and it will be included in the present model. Aggregate demand in this case is measured as domestic consumption plus imports and less exports for agricultural products, and is expressed in 1958 pesos.

Some past and recent studies have suggested that an important factor in influencing technological change and productivity of agriculture is education. Griliches [48] included the average education of the rural farm population as a variable in estimating the aggregate agricultural production function for the United States. In another study, Griliches [50] placed further emphasis on research, extension, and education in production function analysis for agriculture, with conclusive results as to the relevance of such inputs.

In a study involving some international comparisons, Hayami [51] used the variable "literacy ratios" and "School enrollment ratio for the first and second levels of education" in a production function analysis. For both definitions, Hayami found education to be a relevant variable for explaining the productivity gap among selected countries. Thus, it is reasonable to include education as an explanatory variable of productivity changes in agriculture.

In this study, education is measured as the ratio between students who had finished the rural education program and enrolled students for all the institutions of rural education in the country. The rural education refers to a six year program and includes primary school training and some training in farm practices.

Another important variable that is expected to affect productivity changes in Colombian agriculture is the amount of credit provided to producers. In a recent study, Colyer and Jimenez [28] used the variable "supervised credit" in a functional framework analyzing its role in agricultural development in some regions in Colombia and found it highly significant. The indication is that credit makes some productivity changes possible. Furthermore, agricultural credit allows producers to buy the correct quantity of inputs at the right time. To the extent that this occurs, credit is a factor associated with larger total productivity and technological gains in agriculture.

Finally, the weather variable is expected to influence production and productivity levels in agriculture. In this case, the weather variable was defined as the annual deviation of the overall average rainfall for the period 1950-1971. The deviations are expressed in index form, with 1958 = 100.0.

Based on the above discussion, the following relationship is used to determine the sources of productivity change in Colombia's agriculture.

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6) \qquad (16)$$

where

Y = total factor productivity (index) derived in (15);

X_1 = government expenditures on research and extension in 1958 pesos;

X_2 = government expenditures on technical assistance in 1958 pesos;

X_3 = aggregate demand for farm commodities, valued in 1958 pesos;

X_4 = education, as the school completion ratio in rural technical schools;

X_5 = agricultural credit corresponding to total of new loans in 1958 pesos; and

X_6 = weather, as variation of overall average precipitation (index 1958 = 100).

Since the primary concern is on changes and the data are annual data, a multiplicative model was developed as follows:

$$Y = a_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} e^{\varepsilon} \qquad (17)$$

which can be expressed in log form as:

$$\log Y = \log a_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + \beta_6 \log X_6 + \varepsilon \qquad (18)$$

where

Y and X_i (i = 1, 2, 3, 4, 5, 6) are defined as before;

e = base of natural logarithms; and

ε_i = disturbance term, by assumption normally distributed with mean zero and variance ∂^2.

Equation (18) is linear with respect to log a_0 and the β's and thus can be estimated by ordinary least squares.

Time Period Selected and Data Sources

Selection of the time period was made considering that a sufficiently long period should be considered to be representative of the pattern of behavior of Colombia's agriculture. By the time the data collecting work for this study was initiated the latest figures reported were for the year 1971. A review of the data collecting system employed for agriculture in Colombia as well as the data availability indicated that prior to 1950, there existed limited types of information, but not sufficient data of the nature necessary for this study. Given these considerations, the period, 1950-1971, was selected. Most production and input data were obtained from government agencies including the Ministry of Agriculture and the Office of National Planning. DANE[7] and Banco de la Republica[8] were other major sources used.

Production data were obtained in both physical production and value of production. Included are the 18 most important crop products in Colombian agriculture: coffee, cotton, sugarcane, non-centrifugal sugarcane (panela), rice, plantains, corn, potatoes, cassava, sorghum, soybeans, sesame, wheat, cocoa, dry beans, tobacco, barley and banana. The data for livestock production were classified into livestock production and livestock products. Livestock production includes beef cattle, hogs, sheep and goat production, while livestock products were defined to include milk, eggs, poultry and wool, covering the most important animal products in the country.

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[7]DANE is National Administrative Department of Statistics, in charge of collecting and reporting official statistics.

[8]Banco de la Republica is the central bank in Colombia.

Inputs are classified into five categories: (1) purchased inputs, defined as intermediate inputs used in a single production period, e.g., fertilizers, seeds, concentrates and pesticides; (2) land, defined as cropped land and pasture land; (3) labor, defined as economically active population adjusted by unemployment; (4) livestock capital, defined as interest on the value of livestock inventories; and (5) power, defined as interest on value of selected farm machinery and burden animals most frequently employed in Colombia's agriculture.

Monetary values are expressed in 1958 prices to avoid the problem of the effects of price changes. The price deflator used was the index of implicit prices of gross national product which is the best index available for this purpose in Colombia.

The procedures described in this chapter are applied to both the crop and livestock sectors. The total productivity model is applied to the whole agricultural sector given the nature of the data involved and their availability. The results, in that order, are reported in Chapter IV.

CHAPTER IV

SOURCES OF GROWTH

Introduction

The purposes of this chapter are: (1) to present the estimates of aggregate agricultural production functions and test and relationships hypothesized in the framework of the Cobb-Douglas model; (2) to present some related estimates developed to support the analysis; and (3) to identify and evaluate the sources of output and productivity growth in Colombia's agriculture. The significance and interpretation of parameter estimates are used to establish an accounting procedure to explain the changes in partial productivities.

Estimates are presented separately for the crop and livestock subsectors, which allows for comparisons between productivity and efficiency in the use of resources. In the final section, a model for the whole sector is presented to analyze the sources of total productivity. That section of the chapter deals with the total productivity index and the estimates of the sources of total productivity growth and technological change, focusing on non-traditional inputs.

Crops

The production function model estimated for the crop sector is presented in this section. The parameter estimates are statistically tested and used for further interpretation and analysis.

Total Crop Output

The production function expresses the total value of crop output as a function of four categories of inputs: (1) intermediate purchased inputs, including seeds, fertilizers and pesticides is expressed as an average index; (2) hectares of cropped land; (3) power, expressed as interest charges on both machinery and draft animal investment; and (4) labor, expressed as the number of man days employed, adjusted by unemployment.[1]

Estimation of the production function for the crop sector was undertaken initially along the lines of the conventional Cobb-Douglas function as discussed in Chapter III. The main results are summarized in Table IV. The two regressions differ slightly, depending on which measure is used for seeds in the purchased inputs variable.

Equation (1) uses "total quantity of seeds," the estimator for which is significant only at the 0.10 level. When the improved seeds variable is used (equation 2), the coefficient for purchased inputs is significant (0.05 level). The remaining coefficients in the second equation become smaller compared to equation (1), especially labor which loses some statistical significance in the latter regression.[2]

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[1]The data are presented in Appendix C. The monetary values all are based on constant 1958 pesos.

[2]The improved seeds values were defined as an index of quantity of seeds weighted by the index of improved seeds. The coefficients in equation (2) are slightly lower than those in equation (1). Improved seeds in Colombia were first developed or adopted by government agencies which continue to control their reproduction and all imports when these are made. Given this situation, the rationale for the slightly lower coefficients is that the improved seeds variable catches some of these institutional effects, including research and extension efforts.

TABLE IV

COLOMBIA: ESTIMATES OF AGGREGATE CROP PRODUCTION FUNCTIONS

Variables	Regression Coefficients and t-Values[a] Equation (1)	Equation (2)
X_1 (Purchased Inputs)	0.065 (1.543)*	--
X_1' (Purchased Inputs)	--	0.120 (2.518)**
X_2 (Land)	0.375 (1.695)*	0.313 (1.550)*
X_3 (Power)	0.200 (3.285)***	0.162 (2.738)***
X_4 (Labor)	0.715 (2.400)**	0.475 (1.607)*
Constant Term	-0.982	1.900
SE	0.039	0.035
F statistic	134.470	163.132
$\bar{R}^2$	0.962	0.968
D-W	1.173	1.018
Sum of Coefficients	1.353	1.070

[a]The numbers in parentheses are the t-values. $\bar{R}^2$ is adjusted for degrees of freedom. The variables are expressed in logarithms. Equation (1) uses the quantity of seeds variable. Equation (2) uses the quantity of improved seeds variable.

*Significant at the 0.10 level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

The equations provided by both of these regressions exhibit a good statistical fit as indicated by the R^2 values of over 96 percent in each equation. However, the Durbin-Watson test is inconclusive in both cases. Furthermore, the correlation among dependent variables is high and the correlation coefficients are highly significant (Table V).

TABLE V

MATRIX OF SIMPLE CORRELATION COEFFICIENTS AMONG VARIABLES IN THE CROP PRODUCTION FUNCTION

Variables	Variable				
	Y	X_1	X_2	X_3	X_4
Y	1.000	--	--	--	--
X_1 (Purchased Inputs)	0.964	1.000	--	--	--
X_2 (Land)	0.923	0.908	1.000	--	--
X_3 (Power)	0.900	0.860	0.802	1.000	--
X_4 (Labor)	0.948	0.947	0.890	0.801	1.000

These results indicate that there may be some autocorrelation of the residuals and that multicollinearity is a major problem. The latter situation is expected to a certain extent, given the possible complementarities among some of the inputs. Multicollinearity increases the variances of the least squares estimators so that the estimated coefficients become imprecise. On the other hand, autocorrelation if present, makes least squares estimates of the regression coefficients biased and inefficient.

In an attempt to overcome these problems, the model was re-estimated using Durbin's method [42]. This procedure has been developed to correct the autocorrelation problem, but since adjusted first differences are involved in the procedure, it can also help mitigate multicollinearity.[3] For purchased inputs, the improved seed variable was used in this case. The main results of applying Durbin's estimation method are presented in Table VI, and the correlation coefficients are presented in Table VII. The correlation coefficients between explanatory variables are generally reduced, indicating that multicollinearity has been reduced to some extent by Durbin's method. However, the method is much more successful in mitigating the autocorrelation problem. The new Durbin-Watson statistic (2.07) does not allow rejection of the zero serial correlation hypothesis.

From Table IV (equation 2) and Table VI, it can be seen that the coefficients for the variables exhibit the same order of magnitude relative to each other. Even more important, the most significant variables are the same in both sets of regressions -- namely purchased inputs and power. Thus, the two regression equations estimated are similar under these criteria. The effect of the transformation is an R^2 value slightly reduced in the latter case (0.88) but still good. The gain from using Durbin's estimation method is greater statistical reliability in the parameter estimates. Given the above considerations, the estimates

[3]The method is explained in Appendix B.

TABLE VI

COLOMBIA: ESTIMATE OF AGGREGATE CROP PRODUCTION FUNCTION USING DURBIN'S METHOD

Variables	Regression Coefficients and t-Values[a]
X_1 (Purchased Inputs)	0.100 (1.860)**
X_2 (Land)	0.370 (1.758)**
X_3 (Power)	0.221 (3.213)***
X_4 (Labor)	0.591 (1.802)**
Constant Term	0.740 (0.594)
SE	0.036
F Statistic	36.868
$\bar{R}^2$	0.880
D-W[b]	2.070
Sum of Coefficients	1.282

[a]The numbers in parentheses are the t-values. $\bar{R}^2$ is adjusted for degrees of freedom. The variables are expressed in logarithms.

[b]The critical value for the Durbin-Watson test (negative autoregression) is 2.46 at the 0.01 significance level. Then, this test indicates evidence of no autoregression.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

obtained using Durbin's method are used for the remaining analyses. The final form of the aggregate crop production function is expressed in equation (1) below:

$$\log Y = \underset{(0.594)}{1.316} + \underset{(1.860)}{0.100} \log X_1 + \underset{(1.758)}{0.370} \log X_2 + \underset{(3.213)}{0.221}$$

$$\log X_3 + \underset{(1.802)}{0.591} \log X_4 + e \qquad (1)$$

where

Y = aggregate crop output valued in 1958 pesos

X_1, X_2, X_3, and X_4 are purchased inputs, land, power, and labor respectively and the numbers in parentheses are the t-values.[4]

TABLE VII

MATRIX OF SIMPLE CORRELATION COEFFICIENTS AMONG VARIABLES IN CROP PRODUCTION FUNCTION USING DURBIN'S METHOD

Variables	Y	X_1	X_2	X_3	X_4
Y	1.000	--	--	--	--
X_1 (Purchased Inputs)	0.875	1.000	--	--	--
X_2 (Land)	0.792	0.761	1.000	--	--
X_3 (Power)	0.757	0.545	0.547	1.000	--
X_4 (Labor)	0.902	0.909	0.821	0.626	1.000

[4]The intercept for the untransformed observations is α, where $\alpha^* = \alpha(1 - \hat{\rho})$, and $\alpha = \frac{\alpha^*}{1-\hat{\rho}}$ α^* and $\hat{\rho}$ are obtained using Durbin's method. In this case, $\alpha = \frac{0.7402}{1-0.4378} = 1.316$

The coefficient estimates in the above relationship are the factor production elasticities, or:

$$\frac{\partial \log Y}{\partial \log X_1} = \frac{\frac{1}{Y}\,\partial Y}{\frac{1}{X}\,\partial X} = \frac{\partial Y}{\partial X}\,\frac{X}{Y} = \hat{\beta}_i \qquad (i=1,\ 2,\ 3,\ 4)$$

where $\hat{\beta}_i$ refers to the estimated regression coefficient for the ith input.

The crop production function exhibits slightly increasing returns to scale as indicated by the sum of the elasticity coefficients (1.28). However, this sum is not significantly different from one.[5]

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[5]The test for constant returns to scale was made by setting:

$$H_0: \ \beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$$

This hypothesis imposes the constraint

$$\beta_4 = 1 - \beta_1 - \beta_2 - \beta_3$$

to define a restricted model

$$Y' = \beta_0 + \beta_1 X_1' + \beta_2 X_2' + \beta_3 X_3' + (1 - \beta_1 - \beta_2 - \beta_3) X_4'$$

$$Y' - X_4' = \beta_0 + \beta_1 (X_1' - X_4') + \beta_2 (X_2' - X_4') + \beta_3 (X_3' - X_4')$$

where

$Y' = \log Y$, $X_1' = \log X_1$ and similarly for the other variables. The error sum of squares of this restricted model is compared to the error sum of squares of the unrestricted model. The appropriate F statistics is

$$F = \frac{(\text{ESS res.} - \text{ESS unrest.})\ df_1 - df_2}{\text{ESS unrest.}/df_2}$$

where

ESS restr. = error sum of squares of the restricted model,
ESS unrestr. = error sum of squares of the unrestricted model,
df_1 = degrees of freedom in the restricted model, and
df_2 = degress of freedom in the unrestricted model.

In this case, the values obtained are

$$F = \frac{(0.0256790 - 0.02135143)\ /\ 1}{0.02135143\ /\ 16} = 3.24$$

F (1, 16) = 4.49 (0.05 level of significance). Therefore, the conclusion is that the null hypothesis is rejected. See Huang [56].

Since the study is based on national aggregates the inference is that the crop sector in the aggregate exhibits nearly constant returns to scale, with a slight tendency to exhibit increasing returns. Increasing returns means that a proportional increase in the quantity of inputs results in proportionally greater increases in output, that is, a 10 percent increase in all inputs will result in an output increase greater than 10 percent.

The individual elasticity estimates indicate the proportional increase in output when a single factor is expanded, while the other factors are held constant. For example, a 10 percent increase in intermediate purchased inputs will result in one percent increase in output, ceteris paribus. Similarly, a 10 percent increase in land input will result in 3.7 percent increase in output. A 10 percent increase in the power used in the crop sector will result in 2.2 percent of increase in output. Finally, a 10 percent increase in the labor input will result in 5.9 percent increase in output, ceteris paribus.

The actual increase in output is a combined effect, since the inputs tend to be used together. However, to give an idea of individual factors' importance in that joint effect, note that the factors which have had the largest increases in utilization are intermediate purchased inputs and power. Intermediate purchased inputs have increased at a rate of 12 percent annually, 1950 to 1971. This increase alone increased output by 1.2 percent annually. Power has increased by 4.2 percent annually, which increased output by 1.0 percent.[6] Since the

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[6]These estimates are obtained by weighting the estimated elasticities by the percent increases in inputs.

actual growth of output took place at a rate of 3.23 percent, power and purchased input together accounted for two thirds of this. The statistical evidence indicates that purchased inputs and power contributed the most (among the inputs examined) to increased crop output in Colombia from 1950 to 1971.

Value of Marginal Products of Inputs

The elasticity estimates (η) are used to estimate the value of marginal product for each of the inputs considered. For the case of purchased inputs,

$$\eta_{X_1,Y} = \frac{dY}{dX_1}\frac{X_1}{Y} = \frac{\frac{dY}{dX}}{\frac{\bar{Y}}{\bar{X}}} = \frac{MP}{AP} = 0.100$$

where the average product, AP, is evaluted at the geometric means of input and output values and MP is the marginal product of the input. In this case:[7]

$$\overline{\log Y} = \frac{1}{n}\Sigma \log Y_i = \frac{1}{22}(185.089) = 8.413$$

$$\bar{Y} = \text{antilog } 8.413 = \$4505.87$$

Similarly,

$$\overline{\log X} = 4.757 \qquad \bar{X} = 116.498$$

To obtain:

$$MP = \eta_{X,Y}\frac{\bar{Y}}{\bar{X}} = 0.100\left(\frac{\$4505.87}{116.498}\right) = \$3.87$$

For each one unit increase in the purchased inputs index, the value of output increased by \$3.87 on the average. To gain a better

[7]The data used are those of inputs and output in crop production.

interpretation, the coefficient estimate of purchased inputs is defined as the expenditures on these inputs. This estimate of 0.21 is used as above,

$$MP = 0.21 \left(\frac{\$4505.87}{\$\ 590.93}\right) = \$1.60$$

where \$590.93 (million pesos) is the average expenditure on purchased inputs.[8]

This means that for each additional peso spent on intermediate purchased inputs, the value of output increased by \$1.60. The values of marginal products for the different inputs considered are presented in Table VIII. The figures contained in column (4) of the table are the values of marginal products for each input since output was given in monetary values. We can compare each value of marginal product (VMP) to the price of each input to determine if the inputs are being used in the economic optimum quantities at the national level. If value of marginal product is greater than the price of the input, it is worthwhile to expand the use of the input since the value of extra output increases more than the extra cost of the input. When value of marginal product equals the price of the input, the optimal situation exists and the input is used in the correct amount from an economic viewpoint.

An additional peso spent on intermediate purchased inputs leads to an increase of \$1.60 on value of output, which represents a considerable social gain. For power, each peso of additional expenditures leads to an increase of \$1.27 in value of output, which means net \$0.27 for each peso of additional expenditure. The value of marginal product of one

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[8]The model estimated with purchased inputs as the expenditures on these inputs gave similar estimates to those used in Table VIII and it is not necessary to present them since they are not used in further interpretation except for the purchased inputs coefficient.

hectare of land was estimated at $547.30 but the rent paid out per hectare was $303.[9]

TABLE VIII

COLOMBIA: ESTIMATES OF VALUE OF MARGINAL PRODUCTIVITIES OF INPUTS IN CROP PRODUCTION

Inputs (1)	Elasticity Coefficient (2)	Average Product[a] (1958 pesos) (3)	Value of Marginal Product (1958 pesos) (4)	Input Price (1958 pesos) (5)
Purchased Inputs				
A[b]	0.100	38.67	3.87	--
B[c]	0.210	7.62	1.60	1.00
Land[d]	0.370	1479.17	547.30	303.00
Power[c]	0.221	5.76	1.27	1.00
Labor[e]	0.590	13.96	8.24	8.50

[a]Estimated at the geometric mean of output and input values.

[b]Index unit points as units.

[c]1958 pesos as unit.

[d]Hectares as unit.

[e]Man-days as a unit.

[9]The value per hectare was calculated on an average of $2019.84 for cropped land. Applying a 15 percent rate to reflect the social opportunity cost of those funds, the figure obtained was $303, which indicates the cost per hectare of cropped land for these purposes. Estimates of the Agriculture Finance Fund are that 15 percent of the land value is an appropriate measure of the land rent.

The above increases represent considerable social gains, and indicate the benefits of the expansion in use of these inputs. The implication is that purchased inputs, land and power are being used below the economic optimum at the national level. Additional use of these inputs will add significantly more to the value of crop production than to cost by employing more of these inputs. The indication that the land input in crop production at the national level has been used below the economically optimum level is especially important. It means that this basic factor in crop production has been underutilized, in spite of its scarcity in the country. In the aggregate crop sector, the use of purchased inputs, land and power can be expanded to obtain higher levels of production in an economically efficient way.

The average daily wage rate for labor was about $8.50 during the study period. This value compared to the value of marginal product estimated for labor, $8.24, indicates that some surplus labor was utilized in crop production, but not of a significantly large magnitude. In an economic sense, the situation concerning labor in crop production in Colombia was almost one of equilibrium. This situation concerning labor is acceptable from a social objective point of view, since a role that agriculture has to play in the country is to provide employment so that the unemployment situation does not become worse.

Pattern of Value of Marginal Productivity

It is interesting to determine the pattern of values of marginal productivities through time as a basis for understanding trends in both efficiency and use of resources in the crop sector. Three points in time were selected to make inferences about this situation: 1950, 1960 and 1970. The corresponding estimates are presented in Table IX which contains the ratios of the value of marginal products and the input price for each factor considered. A ratio equal to 1.00 indicates perfect efficiency, in the sense that the input is used at the economically optimum level. For purchased inputs, the trend has been toward an efficient use; for 1970 one peso spent in this input resulted in an increase of output of $1.41. The case of land is similar, where one peso spent in the input resulted in an additional output of $1.89.[10] For power, the trend has been similarly from low levels to greater levels of efficiency, and for 1970, one additional peso spent in this input resulted in an increase in the value of output of $1.31. The indication for these inputs is that the trend in their use is toward optimum levels, but without reaching those levels. Purchased inputs, land and power have been used at lower than optimum levels in crop production over time. There have been significant production gains from the expanded use of these inputs. The above estimates indicate the low levels of utilization of those inputs in crop production relative to their productivities. An obvious explanation of the trends of the above inputs toward more efficient use is that producers are becoming aware of the opportunities for an expanded production. This explanation is supported by the case of commercial farmers which through a better information on prices and markets have been able to make better decisiond concerning

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[10]Land rents were calculated by applying the average interest rate charged by banks for agricultural loans to the values per hectare of cropped land. Estimates from Fondo Financiero Agropecuario were employed in this case. The estimated land rent per hectare of cropped land were $181, $259 and $349, respectively, which compared to the value of marginal products of $462.70, $508.70 and $660.79 give the values reported in Table IX.

the use and combination of resources in production. Another partial explanation for that situation is simply that, given the low levels of efficiency in using resources in the former years, especially the 1950s, it has been relatively easier to move to higher levels of efficiency, mainly in the case of resources which are costly to farmers and not plentiful in supply.

TABLE IX

COLOMBIA: RATIOS OF VALUE OF MARGINAL PRODUCTIVITIES IN CROP PRODUCTION TO INPUT PRICES FOR SEVERAL YEARS

Factor	Year		
	1950	1960	1970
Purchased Inputs	2.08	1.77	1.41
Land	2.55	1.96	1.89
Power	1.58	1.38	1.31
Labor	1.35	0.88	0.87

For labor, the values of marginal productivity per man-day were $6.21, $8.54 and $9.81 which compared to the wages of $4.60, $9.86 and $11.08, respectively, given the values reported in Table IX.[11] The indication is that in the 1950s, labor was employed in an economic and

[11]Data on wages obtained from Departamento Administrativo Nacional de Estadistica - DANE.

efficient way. However, by 1960 there is evidence of some slight over-employment in the sector. Since 1960, labor in crop production has been employed near optimum levels with a continued indication of a surplus. The capital input represented by inputs other than labor has not increased substantially in the crop sector, precluding absorption of additional labor in a more productive way. This situation suggests low levels of investment in the crop sector.

Research and Extension

There is a non-conventional input which has proven to be important in influencing farm output in several countries, namely research and extension [50, 51, 55]. Data are available to consider this variable along with the other inputs for the crop sector. To show the influence of research and extension on the value of crop output in Colombia, a production function including this input is estimated (Table X). Durbin's estimation method is used to be consistent with previous estimates in this study. The research and extension variable is highly significant whether lagged one year (equation 2) or not (equation 1). Also, the correlation coefficient between crop output and research and extension is 0.77 and highly significant, indicating a considerable positive relationship. The sum of coefficients in this regression model is about 1.5, which is significantly different from one. Inclusion of the research and extension variable makes the other inputs more statistically significant in influencing crop output in general, and the indication is of increasing returns more markedly than before, when that variable was not included. The elasticity of crop output with respect to research and extension does not appear high (0.092 and 0.100 in

TABLE X

COLOMBIA: ESTIMATES OF AGGREGATE CROP PRODUCTION FUNCTIONS INCLUDING THE RESEARCH AND EXTENSION VARIABLE[a]

Variable	Equation (1)	Equation (2)
X_1 (Purchased Inputs)	0.086 (1.785)**	0.097 (1.845)**
X_2 (Land)	0.345 (2.982)***	0.393 (3.440)***
X_3 (Power)	0.216 (5.468)***	0.180 (4.202)***
X_4 (Labor)	0.722 (3.863)***	0.673 (3.220)***
X_5 (Research and Extension)[b]	0.092 (5.515)***	
X_6 (Research and Extension)[b]		0.100 (4.841)***
Constant Term	4.533	3.331
SE	0.028	0.029
F-Statistic	96.480	95.381
$\overline{R}^2$	0.982	0.971
DW	2.065	1.936

[a]The numbers in parentheses are the t-values. $\overline{R}^2$ is adjusted for degrees of freedom. The variables are expressed in logarithms.

[b]X_5 refers to current expenditures on research and extension, and X_6 to those values lagged one year.

[c]The Durbin-Watson test indicates evidence of no autoregression in any of the regressions, since the critical values are $d_\ell = 0.66$ and $d_\mu = 1.69$ at the 0.01 level of significance.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

equations 1 and 2 in Table X) but is within the range of those values estimated in some international studies. For instance, Griliches [50] reports elasticities of research and extension in the range of 0.04 to 0.07 for the U.S. and Hayami [51] reports values in the range of 0.06 to 0.11 for a sample of 38 countries, including Colombia. The above result suggests that if specific crop research activities were related to crop output, a stronger relationship with output would be found. There is evidence that this has been the case for specific crops in Colombia [3, 54, 86]. The coefficient for research and extension remains about the same when this variable is lagged one year. The indication is that the benefits of research and extension programs are spread over time. This is to be expected, since research programs often do not show immediate results.

Labor and Land Productivity

It is useful to derive the relationships between labor and land productivity and the explanatory variables used in the preceding analysis. Changes in output per man can be considered to be the result of changes in capital per worker and the quality of labor. Changes in land productivity can be considered to be the result of changes in the quantities and qualities of other physical inputs used, land quality improvements, and technology which are not embodied in the physical factors.

Labor Productivity

Labor productivity (output per man-year) has increased at a rate of 2.10 percent annually since 1950. Productivity increased from $2420 per man-year in 1950 to $3721 in 1971, representing a 54 percent increase. These gains in labor productivity in crop production in Colombia do not appear as low as many authors assume for developing countries [26]. Equation (1) (Table X) expresses the total production function. From that, a relationship between the average labor product (expression for labor productivity) and the other variables can be obtained by dividing total output by labor input.[12] The elasticity estimates indicate that purchased inputs, power and land are important

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[12]
$$\frac{Y}{X_4} = \frac{3.318\ X_1^{0.086}\ X_2^{0.345}\ X_3^{0.216}\ X_4^{0.722}\ X_5^{0.092}}{X_4}$$
$$= 3.318\ X_1^{0.086}\ X_2^{0.345}\ X_3^{0.216}\ X_4^{0.722}\ X_5^{0.092}\ \frac{1}{X_4^{0.278}}$$

where the intercept is obtained through Durbin's method as:

$$\alpha = \frac{\alpha^*}{1-\hat{\rho}} = \frac{4.533}{1-(-0.366)} = 3.318$$

From the above expression, we can see that the exponents denote the elasticities in each case. In the structural relationship they are the same as those estimated in the production function. This is so because the effect of an input is directly in production. For purchased inputs,

$$\frac{\partial \frac{Y}{X_4}}{\partial X_1} \cdot \frac{X_1}{\frac{Y}{X_4}} = \text{elasticity of labor productivity with respect to purchased inputs.}$$

$$= 3.318\ (0.086)\ X_1^{-0.914}\ X_2^{0.345}\ X_3^{0.216}\ X_5^{0.092}\ \frac{1}{X_4^{0.278}} \cdot \frac{X_1}{\frac{Y}{X_4}}$$

$$= 3.318\ (0.086)\ X_1^{0.086}\ X_2^{0.345}\ X_3^{0.216}\ X_5^{0.092}\ \frac{1}{X_4^{0.278}}\ \frac{1}{\frac{Y}{X_4}}$$

$$= 0.086\ \frac{Y}{X_4}\ \frac{1}{\frac{Y}{X_4}} = 0.086$$

And similarly for the other inputs.

inputs in influencing labor productivity. A 10 percent increase in purchased inputs will increase labor productivity by 0.86 percent, ceteris paribus. Similarly a 10 percent increase in land will increase labor productivity by 3.45 percent and a 10 percent increase in the power input will increase labor productivity by 2.16 percent. Finally a 10 percent increase in research and extension expenditures will increase labor productivity by 0.92 percent, ceteris paribus. These coefficients can be weighted by the actual change in use of the inputs over time to indicate the importance of each input in affecting labor productivity. The factor share method is used to determine the impact of each input. Actual elasticity estimates are used and it is assumed that the factors considered account for all the variation in output per man-year. The elasticity estimates used are those presented in Table X: 0.086 for purchased inputs, 0.345 for land, 0.216 for power and 0.092 for research and extension. The approximation equation is:

$$\mathring{Y} = 0.086\ \mathring{X}_1 + 0.345\ \mathring{X}_2 + 0.216\ \mathring{X}_3 + 0.092\ \mathring{X}_4 + e \qquad (2)$$

where

Y = output per man-year,

X_1 = purchased inputs per man-year,

X_2 = land per man-year,

X_3 = power per man-year, and

X_4 = research and extension per man-year.

The symbol $\mathring{Y}$ refers to annual percentage changes in labor productivity and the $\mathring{X}$s refer to percentage changes in each factor. The symbol e is the residual to account for error in the estimation of parameters and any missing factors. The results of applying the above equation are presented in Table XI.

TABLE XI

COLOMBIA: CONTRIBUTION OF SEVERAL FACTORS TO LABOR PRODUCTIVITY IN CROPS

Factor	Annual Change (Rate) ($\dot{X}$)	Regression Coefficient ($\hat{\beta}$)	Contribution[a] ($\hat{\beta}\dot{X}$)	Relative Contribution[b] (Percentage)
Purchased Inputs	0.1072	0.086	0.0092	43.8
Land	0.0043	0.345	0.0015	7.1
Power	0.0304	0.216	0.0066	31.4
Research-Extension	0.0603	0.092	0.0055	26.2
Other Factors[c]				-8.5
Production per man-year ($\dot{Y}$)	0.0210	--	--	--

[a]Contribution to change in labor productivity as evaluated by equation (2).

[b]Total change in production per man-year = 100.0

[c]Calculated as the residual.

Purchased inputs used by labor have increased slightly over 10 percent annually since 1950 and this increase only has increased labor productivity by 0.92 percent. Land only increased at a rate of 0.43 percent annually, resulting in an increase of 0.15 percent in labor productivity. Power increased at a rate of 2.04 percent, resulting in an increase of 0.66% in labor productivity. Research and extension can be thought of as input representing technology advance and adoption. This input has increased at a rate of 6.03 percent annually, with an associated increase in labor productivity of 0.55 percent. Labor productivity increased by 2.10 percent annually from 1950 to 1971. Purchased inputs and power accounted for three-fifths of the change (Table XI). The relative scarcity of land and the small increase in land per worker in the sector appears to be a major reason for the small contribution of this input to total labor productivity change. Research and extension which is a proxy for nonconventional inputs and technology, explain approximately one-fourth of labor productivity increases.

There is some indication that there are negative effects of other factors influencing labor productivity. These can be considered as constraints in improving labor productivity (besides that part that correspond to statistical error). It is difficult to introduce other factors that might be important in this case due to the difficulty of quantification. Customs, personal attitudes, and habits might be some of those factors.

Contributions of Physical Inputs and Technology to Labor Productivity Growth

As explained in pages 38 and 39 in Chapter III, an explicit formulation can be used to account for the contribution of technology to labor productivity if the function exhibits constant returns to scale. Using this method, the effect of technology is derived as the residual, i.e., technology accounts for all output not explained by physical inputs. Using coefficients for the physical inputs taken from Table VI:

$$\dot{Y} = \frac{\Delta A}{A} + 0.100\ \dot{i} + 0.221\ \dot{p} + 0.270\ \dot{\ell} \qquad (3)$$

where

$\dot{Y}$ = annual change in value of output per man-year,

$\dot{i}$ = annual change in purchased inputs per man-year,

$\dot{p}$ = annual change in power per man-year,

$\dot{\ell}$ = annual change in land per man-year.

In this case, $\dot{Y} = \frac{\Delta A}{A} + 0.1000\ (0.1072) + 0.2210\ (0.0304) + 0.3700\ (0.0043)$

or $0.0210 = \frac{\Delta A}{A} + 0.0107 + 0.0067 + 0.0016$

$$0.0210 = \frac{\Delta A}{A} + 0.0190$$

$$\frac{\Delta A}{A} = 0.0020$$

The physical inputs provided to labor explained 90.5 percent of the total change in value of output per unit of labor. Technical change explained 9.5 percent of such change, and is a proxy for improvements in education, working conditions and other factors that lead to larger productivity.

The evidence presented points out that the increases in labor productivity obtained during the study period in the crop sector have been primarily due to increases in tangible or physical capital per unit of labor, particularly intermediate inputs and power. In addition, research and extension and technology were also of some importance.

In general, the evidence indicates that increases in labor productivity in the crop sector in Colombia are mostly associated with increases in capital inputs such as land, roads, machinery and power, and intermediate inputs. These capital items especially the last two categories, have been increasingly combined with labor. They have facilitated improvements in the role of labor in production and, therefore, labor productivity.

Land Productivity

Levels of land productivity are mainly the result of quantity and quality of physical inputs applied, land improvements, and better technology that tend to make land more productive. The output elasticities presented in Table X indicate that the effect on output per unit of land will be proportionally large for changes in purchased inputs, power and labor. For research and extension, the coefficient is of a reasonable size and statistically significant. As in the case of crops, the elasticity estimates can be weighted by the annual changes in input use to determine the contribution of the several factors to land productivity. Intermediate purchased inputs, improved seeds, fertilizers and pesticides applied to land increased at a rate of 10 percent annually from 1950 to 1971. This increase alone tended to increase land productivity by 0.86 percent. Use of the power input increased by two percent, which is associated with an increase in land productivity of 0.43 percent. Research and extension expenditures per hectare increased at a rate of five percent during the period and are associated with an increase in land productivity of 0.46 percent. This estimate supports the relevance of that factor. Land productivity increased from $1251 per hectare in 1950 to $1756 per hectare in 1971 -- a 40 percent increase -- which is smaller than the expansion shown by labor productivity during the same period. This change represents an increase in land productivity of 1.63 percent annually between 1950 and 1971, which compared to the above estimates, gives an idea of the importance of those factors in influencing land productivity.

The indication is that physical inputs play an important role in inducing land productivity gains, mainly intermediate inputs and power. In the first group, the use of fertilizers increased at a rate of 14 percent annually since 1950 which is the largest increase in that group of inputs.

Technology allows less labor to be employed per unit of land. This is especially the case, if technology adopted is labor-saving. The indication for the crop sector is that this has occurred even though the bias is not very strong. Labor used per hectare has changed from 0.51 man-years in 1950 to 0.47 man-years in 1971.

Livestock

The production function model estimated for the livestock sector is presented in this section. The analysis is conducted in the same order used in the crop section.

Livestock Output

As explained in Chapter III, the inputs considered are (1) concentrates, expressed in tons; (2) land, expressed in hectares of permanent pasture land; (3) livestock capital, defined as interest charges on investment in livestock inventories in 1958 pesos; (4) power, defined as interest charges on both machinery and draft animals' investment; and (5) labor, expressed both as man-years employed and as the wage bill, then adjusted for unemployment.[13] Use of the power

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[13]The data are presented in Appendix C. The monetary values are in constant 1958 pesos.

input is not considerable in livestock farming in the country. For this reason, the power input was omitted from some equation estimates in searching for an appropriate specification of the function.

Initially, the unrestricted Cobb-Douglas function was fitted to the data to obtain an estimate of the aggregate livestock production function. The main results are presented in Table XII. The function provides a very good statistical fit as indicated by a high R^2 value. The F-statistic is highly significant and indicates a strong joint effect of the explanatory variables on the value of livestock output. In addition, there is no evidence of autocorrelation among the residuals as indicated by the Durbin-Watson test. However, correlation among explanatory variables is high. This results in inaccurate regression coefficient estimates. The correlation coefficients are presented in Table XIII. The complementarity between some factors tend to produce high values of some coefficients.

The negative regression coefficient for labor in Table XII indicates negative marginal contribution of labor in livestock output, i.e., negative marginal productivity. Nevertheless, this coefficient is not significantly different from zero. Besides, it is known *a priori* that the situation of negative marginal labor productivity does not hold. Furthermore, the livestock sector in Colombia is not in a situation of excessive labor employed, given its labor absorption capacity.

To mitigate this problem, a second set of estimates was calculated in which labor was defined as the estimated wage bill in livestock

TABLE XII

COLOMBIA: ESTIMATE OF THE AGGREGATE LIVESTOCK PRODUCTION FUNCTION

Variable	Regression Coefficients and t-Values[a]
X_1 (Concentrates)	0.040 (5.739)***
X_2 (Land)	0.857 (1.222)
X_3 (Livestock Capital)	0.809 (2.236)**
X_4 (Labor	-0.289 (-0.815)
Constant Term	-3.820
SE	0.041
F-Statistic	190.086
$\bar{R}^2$	0.962
DW[b]	1.982

[a]The numbers in parentheses are the t-values. The $\bar{R}^2$ is adjusted for degrees of freedom. The variables are expressed in logarithms.

[b]The Durbin-Watson test indicates no evidence of autocorrelation since the critical value is 2.46 (for negative autocorrelation) at the 0.01 significance level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

farming as a proxy for man years. An important observation in this respect is that when man-years employed are used, both family labor and hired labor are included. When the wage bill variable is used only, labor employed "and effectively paid" is included. The wage bill, defined this way, is a proxy for effective labor employed in livestock farming.

TABLE XIII

MATRIX OF SIMPLE CORRELATION COEFFICIENTS AMONG VARIABLES (IN THE LIVESTOCK PRODUCTION FUNCTION FOR COLOMBIA)

Variable	Y	X_1	X_2	X_3	X_4	X_4'	X_5
Y	1.000	--	--	--	--	--	--
X_1 (Concentrates)	0.882	1.000	--	--	--	--	--
X_2 (Land)	0.963	0.782	1.000	--	--	--	--
X_3 (Livestock Capital)	0.921	0.670	0.971	1.000	--	--	--
X_4 (Labor)[a]	0.885	0.696	0.941	0.927	1.000	--	--
X_4' (Labor)[a]	0.928	0.764	0.931	0.918	0.860	1.000	--
X_5 (Power)	0.371	0.549	0.279	0.135	0.165	0.285	1.000

[a]X_4 uses man-years and X_4' uses wage bill for the labor variable.

In seeking more accurate estimates, the first differences transformation using the Durbin's method of estimation was employed, where labor (the wage bill) was considered as effective labor engaged in livestock farming. Also, the power variable is included to allow for a more complete model if possible. The main results are presented in Table XIV. The multicollinearity problem is reduced in this case as indicated by a decrease in the correlation among explanatory variables (Table XV). However, the gain in overcoming multicollinearity was not very large. The indication is that there are strong intrinsic relationships among several of the explanatory variables, and that little can be done about it without removing variables. Fortunately, the multicollinearity problem is always one of degree and the case here is not an extreme one. Nevertheless, the variables have a joint effect which is highly significant, as indicated by the high F-statistic value in the above regression. In addition, it is possible to distinguish the effect and significance of the several variables, as the t-tests indicate. The equation estimated using Durbin's method provides a good statistical fit and is useful for our purposes.

On the basis of the above considerations, the aggregate livestock production function can be expressed as shown by equation (4) below:

$$\text{Log } Y = -5.491 + \underset{(7.703)}{0.037} \log X_1 + \underset{(1.994)}{0.955} \log X_2$$

$$+ \underset{(1.987)}{0.505} \log X_3 + \underset{(1.278)}{0.136} \log X_4 + \underset{(1.965)}{0.097} \log X_5 \quad (4)$$

where

Y = aggregate livestock output valued in 1958 pesos

X_1, X_2, X_3, X_4 and X_5 refer to concentrates, land, livestock capital, labor and power, respectively, and the numbers in parentheses are the t-values.[14]

TABLE XIV

COLOMBIA: ESTIMATE OF AGGREGATE LIVESTOCK PRODUCTION FUNCTION USING DURBIN'S METHOD

Variable	Regression Coefficients and t-Values[a]
X_1 (Concentrate)	0.037 (7.703)***
X_2 (Land)	0.955 (1.994)**
X_3 (Livestock Capital)	0.505 (1.987)**
X_4 (Labor)[b]	0.136 (1.278)
X_5 (Power)	0.097 (1.965)**
Constant Term	-6.430
SE	0.027
F-statistic	38.029
$\bar{R}^2$	0.986
DW[c]	2.076

[a]The numbers in parentheses are the t-values. $\bar{R}^2$ is adjusted for degrees of freedom.

[b]Labor measured as the wage bill.

[c]The Durbin-Watson test indicates no evidence of autocorrelation since the critical value is 1.54 (for positive autoregression) at the 0.01 significance level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

TABLE XV

MATRIX OF SIMPLE CORRELATION COEFFICIENTS AMONG VARIABLES
IN THE LIVESTOCK PRODUCTION FUNCTION
USING DURBIN'S METHOD

Variable	Y	X_1	X_2	X_3	X_4	X_5
Y	1.000					
X_1 (Concentrates)	0.893	1.000				
X_2 (Land)	0.962	0.767	1.000			
X_3 (Livestock Capital)	0.920	0.645	0.796	1.000		
X_4 (Labor)	0.924	0.749	0.725	0.909	1.000	
X_5 (Power)	0.315	0.430	0.178	0.070	0.190	1.000

It should be noted that the inclusion of power resulted in a good statistical fit and significance of all the variables except labor. Power should therefore be included in the specification of the production function. The implication is that power, in spite of not being extensively used for livestock production, makes the effect of the other inputs more significant in influencing output.

[14] The intercept for the untransformed observations is α, where

$\alpha^* = (1 - \hat{\rho})$, and $= \frac{\alpha^*}{1 - \hat{\rho}}$

α^* and $\hat{\rho}$ are obtained using Durbin's method. In this case,

$$\alpha = \frac{-6.430}{1 - (-0.171)} = -5.491$$

The coefficient estimates are the production elasticities with respect to each of the inputs as shown previously. Accordingly, the estimated production elasticities for the livestock sector are: 0.037 for concentrates, 0.955 for land, 0.505 for livestock inventories, 0.136 for hired labor, and 0.097 for power. The size of these coefficient estimates appear to be reasonable for the Colombian livestock sector.

The feed concentrate variable is relevant in influencing livestock output. The increasing importance of this factor among the inputs utilized in livestock production in Colombia is consistent with the statistically significant, positive relationship indicated. The estimated elasticity should not be considered as low, given that concentrates are a single intermediate purchased input and the estimate is at the aggregate level.

The large amount of land used in livestock farming reflects the large role played by this input in total livestock output. But a lower coefficient would be expected a priori because there is no relative scarcity of this input, and livestock is rather extensive with respect to land use. The situation may indicate the dominance of land in livestock production which is generally the case in Colombia. However, if that is the case in the statistical sense, more relevant variables would need to be included to obtain a more accurate coefficient for this input. Unfortunately, there are no previous estimates at the aggregate level in the country that could be used for comparison purposes.

Livestock capital, defined as livestock inventories was found to be important in inducing output changes. The coefficient indicates that a one percent increase in animal inventories will result in an output increase of 0.5 percent. Labor also shows a positive effect on output, but the coefficient was not statistically significant. The coefficient for power is rather small (0.097) but statistically significant, indicating the positive effect on livestock output: a 10 percent increase in this input will result in a 0.97 percent increase of output.

The sum of the coefficients in the production function is 1.73 and significantly different from one.[15] Given that the data are not on a per-farm basis but are national aggregates, this result indicates that at aggregate level the livestock sector enjoys increasing returns to scale. This result indicates that the sector could exploit the economic opportunities available as result of the joint effect of inputs. The remaining analysis in this section will attempt to identify these possibilities through the estimates of marginal productivities of inputs and the identification of the relevant sources of growth in this sector.

Value of Marginal Products of Inputs

The elasticity estimates are used to estimate the value of marginal product for each input. The procedure is identical to that used for crops. The marginal productivity calculations are shown in Table XVI. The corresponding estimates presented in column (4) of this table are the values of marginal products for each category of input, since output is given in monetary values. Comparison of those values, VMP, with

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[15]The sum includes the labor coefficient, 0.136. The test was undertaken in a similar way as for crops, i.e., specifying a constrained model (see p. 56 in this chapter).

input prices can be made at the national aggregate level to make inferences about the use of inputs in the livestock sector.

TABLE XVI

COLOMBIA: ESTIMATES OF THE VALUE OF MARGINAL PRODUCTIVITIES OF INPUTS IN LIVESTOCK PRODUCTION

Input (1)	Elasticity Coefficient (2)	Average Product[a] (3)	Value of Marginal Product[a] (4)	Input Price[a] (5)
X_1 Concentrates[b]	0.03	60,948.00	1828.44	498.00
X_2 Land[c]	0.95	154.03	146.32	240.00
X_3 Livestock Capital[a]	0.51	3.05	1.55	1.00
X_4 Labor (wages)[a]	0.14	3.62	0.51	1.00
X_5 Power[a]	0.09	12.18	1.09	1.00

[a]Measured in 1958 pesos.

[b]Measured in tons.

[c]Measured in hectares.

There are three inputs in the group considered for which the value of marginal product is greater than the price of the input: concentrates, livestock capital, and power. For concentrates, the value of marginal product for a ton of this input estimated at about $1828 greatly exceeds the average price per ton of concentrate estimated at only $498. On a per peso basis, an additional peso spent on concentrates increases output value by $3.67, which is a remarkable gain at the aggregate level.[16] For livestock inventories, the estimate of the value of marginal product indicates that for each peso spent on this input, total livestock output increased by $1.55, which is a significant economic gain. The result suggests that the input was underutilized relative to input productivity. Additional investment in animal inventories will add significantly to value of output in the livestock sector.

The corresponding estimate for power, indicates that for each peso of additional expenditures in this input, livestock output increased by $1.09. This gain is of some consideration and indicates a relatively small level of use of this input and its positive contribution to output increases at the margin.

For land, the value of marginal product of $146 is rather small relative to the estimated average rent at $242 per hectare. The low average product of land in livestock resulted in a small value of marginal product in spite of the relatively high value of the elasticity coefficient.[17] The implication is that there is an excessive amount of land used for livestock production, relative to the marginal contribution of this input to value of output. Land should be used more intensively but not in greater quantity to achieve larger livestock output

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[16]The average expenditure on concentrates was estimated to be $96.427 million for an average of 193,630 tons consumed which gives an average cost per ton of $498. The $3.67 figure is obtained by dividing $1,828 by 498.

[17]The average value of pasture land is estimated in $1616. Applying a 15% rate to this value to reflect the social opportunity cost of these funds, the figure obtained is $242, which is the value of rent cost per hectare of pasture land. Estimates from the Agricultural Finance Fund (FFA) use the 0.15 figure.

at the national level.

The value of marginal product of labor when the wage bill is considered is \$0.51 per additional peso spent. On a per day basis, it means that for each man-day additionally employed, the value of output increased by \$4.34, but the daily wage rate is \$8.50.[18] In the aggregate livestock sector, the situation is one of labor surplus, even though hired labor has a positive effect on livestock output.

The major implication of the above analysis is that concentrates, livestock inventories and power are being used at levels below the optimum economic levels in the livestock sector. The use of these categories of inputs should be expanded to obtain livestock production gains in an efficient way, for they are underutilized relative to input productivities.

The indication given the above results is that the livestock sector in Colombia faces large economic opportunities for output expansion mainly through an increased use of animal inventories and feed concentrates. These inputs, especially the latter have had large increases through time. The power input also showed some potential for output expansion in an efficient way but, not as large as the other inputs.

Value of Marginal Productivities

Trends Over Time

In the analysis of livestock, similar to the case of crops, it is important to determine the trend of value of marginal productivities

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[18]The average daily wage was estimated in \$8.50, so the value of marginal product on a per-day basis is \$0.51 (8.50) = \$4.34.

over time to formulate policies for the future. Estimates of values of marginal products of the inputs for three years are considered -- 1950, 1960 and 1970 -- which show the general trend over time. The corresponding values are expressed as ratios between the values of marginal product and input prices (Table XVII).

TABLE XVII

COLOMBIA: RATIOS OF VALUES OF MARGINAL PRODUCTIVITIES TO INPUT PRICES IN LIVESTOCK PRODUCTION, FOR SELECTED YEARS

Factor	1950	1960	1970
		Values in Pesos	
Concentrates	131.43	3.50	1.20
Land[a]	0.88	0.67	0.62
Livestock Capital	1.34	1.70	1.78
Power	1.55	1.16	1.10
Labor[b]	0.77	0.80	0.90

[a]Land rents estimated from data provided by Fondo Financiero Agropecuario similar as for the crop sector.

[b]Data on wages obtained from Departamento Administrativo Nacional de Estadistica - DANE.

In the case of concentrates, the trend has been a movement toward the optimum. In 1950, there was a remarkable output gain from additional use of the input and it was clearly underutilized. In 1970, there was still some underutilization of the input.

In the case of livestock capital, the input has been underemployed and the trend does not indicate movement towards increased efficiency. There was a decrease in livestock inventories in the 1950s, except for beef cattle which increased only by 8 percent from 1950 to 1960, while in the 1960s the increases were not sustained even though of some consideration.[19] The indication is that livestock capital input has been clearly underutilized through time.

In the case of power, the trend has been toward an optimum use, but there was still underutilization in 1970. For labor, there has been a movement toward an optimum amount of use in the sector, but there was still a surplus in 1970. This does not indicate that a smaller amount of labor has been employed but that some output gains have been achieved in the productive process.

In the case of land, the value of marginal productivities were $127.60, $147.70 and $182.74 per hectare of pasture land for the three time periods, which are compared to the land rent of $145, $220 and $297 per hectare, respectively for the same three periods. The use of the land factor has not been at an economic optimum level, relative to the price of the input, the tendency being toward overemployment of this factor. The situation continued in 1970.

Input use is becoming more efficient in the cases of concentrates, power and labor. Several reasons account for this situation. For the case of concentrates, producers have become aware of the profitability

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[19]Total animal inventories of beef cattle, hogs, sheep and goats decreased by 1.80 percent from 1950 to 1960, and increased by 47 percent from 1960 to 1971.

of the input and there have been remarkable increases in its utilization. The considerable, manifested input productivity can be considered as the reason for movement toward efficiency in the use of concentrates. In the case of power, the input is limited in availability in the sector. Furthermore, it is a costly input. Under these conditions, the use of the input is expected to be below the optimum level due to the income constraints for larger purchases of the input. In the case of labor, the livestock sector has not been a highly labor absorbing activity, although hired labor shows a positive contribution to output. Most activities in livestock production under the current practices in Colombia demand labor more than power. These factors can be considered as major reasons for adjustment on the part of producers in the aggregate toward an efficient use of this input.

In the case of land, the major reason for the persistent inefficient use of the input can be considered to be the latifundia structure which exists in several livestock producing areas in the country. This situation does not provide incentives for an efficient use of land in livestock farming. Furthermore, the situation has not shown any improvement through time.

Finally, in the case of livestock capital, the difficulties that many producers in the sector face to expand animal inventories, such as financial constraints, can be considered a persistent problem that inhibits the achievement of an efficient utilization of the input at the national level. An important observation is that the shifts away from efficiency are larger through time, which implies that the economic opportunities in the use of animal inventories are not being fully exploited.

The above results indicate that the largest potential production in the livestock sector is from the use of concentrates and animal inventories. These two categories of inputs have been used at smaller than optimum levels in livestock production. The power input also shows some potential to increase production, but to a smaller extent.

Labor and Land Productivities

The production function estimates indicate the importance of several factors in influencing output and their impact on the average physical product relationships. To give some idea of the forces that cause changes in labor and land productivities in the livestock sector, it is useful to associate the changes in inputs on that basis with the elasticity coefficient estimates.

Labor Productivity

From the production function estimates (Table XIV), it can be seen that the forces tending to increase average labor productivity in livestock production are concentrates, land, livestock capital and power, the latter to a smaller extent. The coefficients can be weighted by the actual change in inputs over time to make an approximation to the importance of the inputs in affecting labor productivity. The changes refer to the inputs on a per man-year basis and the coefficients used are those in Table XIV.

The approximation equation is:

$$\dot{Y} = 0.037\ \dot{X}_1 + 0.955\ \dot{X}_2 + 0.505\ \dot{X}_3 + 0.097\ \dot{X}_4 + e \qquad (5)$$

where

Y = output per man-year,

X_1 = concentrates per man-year,

X_2 = land per man-year,

X_3 = livestock capital per man-year, and

X_4 = power per man-year.

The symbol $\dot{Y}$ refers to annual percentage change in labor productivity and the $\dot{X}$s refer to the percentage changes in each factor, and e is the residual to account for error in the estimation of parameters and any missing factors. The results of applying the above equation are presented in Table XVIII.

TABLE XVIII

COLOMBIA: CONTRIBUTION OF SEVERAL FACTORS TO LABOR PRODUCTIVITY IN LIVESTOCK, 1950-1971

Factor	Annual Change (Rate) $\dot{X}$	Regression Coefficient β	Contribution[a] $\hat{\beta}\,\dot{X}$	Relative Contribution[b] (Percentage)
X_1 Concentrates	0.4200	0.0370	0.0155	78.2
X_2 Land	0.0002	0.9550	0.0002	1.0
X_3 Livestock Capital	0.0044	0.5050	0.0022	11.1
X_4 Power	0.0036	0.0970	0.0003	1.5
Other Factors[c]				8.2

[a]Contribution to change in labor productivity as evaluated by equation (5).

[b]Total change in production per man-year = 100.0.

[c]Calculated as the residual e.

Concentrates used by labor have increased by 42 percent annually since 1950; this increase alone increased labor productivity by 1.55 percent. Animal inventories increased at an annual increase of 0.44 percent, which leads to an annual increase of 0.22 percent in labor productivity. Land increased at a rate of only 0.02 percent which indicates that this factor is not very important in affecting labor productivity. The actual increase in labor productivity has been 1.98 percent annually from 1950 to 1971. Concentrates and livestock inventories have been the most important inputs in inducing that increase, accounting for about 90 percent of the change.

To obtain further productive employment of labor in the livestock sector, significant increases should be made in other inputs, mainly animal inventories and concentrates. Furthermore, other physical inputs used with labor need to be increased, if both family labor and hired labor are to become more productive in the livestock sector.

Land Productivity

The production function estimates indicate that concentrates, effective labor, animal inventories and power have positive effects on average land productivity. Among these factors, the largest gains are to come from increases in animal inventories as indicated by the coefficient of 0.505. An increase of one percent in animal inventories will lead to a 0.50 percent increase in land productivity for a given quantity of the land input. The analysis in a previous section of this chapter of the value of marginal products reveals the importance of concentrates in livestock production. Concentrates and feeds have been increasingly used in this sector and have played a major role in inducing increases in production per hectare in the livestock sector. Unfortunately, animal inventories have not increased significantly, thus constraining the impact of this input. The stock carrying capacity has increased at a rate of 0.42 percent. However, this increase alone tends to increase output by over 0.2 percent according to the elasticity estimate. The increase in concentrates of about 40 percent that has occurred would lead to an increase of over one percent in land productivity.

The actual increase in land productivity has been 1.96 percent annually since 1950. The increases in utilization of concentrates have played the most important role in this increased land productivity.

The research and extension variable had some effect when the lagged values were considered. However, the corresponding coefficient, 0.033, was small and non-significant when considered in the production function. Research for livestock essentially involves long-term programs. Thus, the effect on current production is not very large, since there was no large scale research program on livestock until recently. The results suggest that the effect of research and extension on livestock production is spread over time, as is the effect of this nonconventional input on land productivity in the livestock sector. The main indication from the above results is that output increases and productivity gains in the livestock sector will come from a more intensive use of land along with a higher stockcarrying capacity and increased feed concentrates supplied to larger animals inventories.

Total Productivity

Increased production at any cost is not a tenable goal because resources are limited and costly. Therefore, it is important to obtain relevant information on forces that are behind total productivity gains, as measured by increases in the output-input ratio. Those forces are expected to be associated with technological change in agriculture, and thus, they should facilitate efficiency improvements in agricultural production. The objective of this section is to determine the most relevant sources of productivity for the whole Colombian agricultural sector, focusing on non-conventional inputs.[20] Usually, the factors involved can be directly affected by the government, so the information to be obtained is important for policy purposes.

Pattern of Total Productivity Index

Mansfields' definition of the total productivity index [70] was used.[21] The total productivity index for Colombia's agricultural sector increased by 44.0 percent during the 1950-71 period, or at an average rate of 1.74 percent annually (Table XIX). These gains indicate that some improvements in the use of resources in agriculture have been accomplished, leading to efficiency gains in the aggregate.

Atkinson [7] reported an increase of 1.6 percent in total productivity during the period, 1950-1967, but he used estimates for only three years. However, there is evidence that further improvements in total productivity of agriculture have occurred, that is, increases in

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[20]The model is explained in the methodology, Chapter III, pp. 40-46.

[21]The index is defined in Chapter III, p. 41.

TABLE XIX

INDEX OF TOTAL PRODUCTIVITY IN THE COLOMBIAN AGRICULTURAL SECTOR

Year	Y	αN	ρC	$\alpha N + \rho C$	TPI (1958 = 100)
1950	74.7	23.81	70.07	93.88	79.6
1951	74.5	23.96	70.29	94.25	79.0
1952	84.1	23.96	70.52	94.48	89.0
1953	82.7	23.96	70.82	94.78	87.2
1954	88.9	24.19	71.71	95.90	92.7
1955	89.2	24.46	72.23	96.69	92.2
1956	92.7	24.74	73.21	97.95	94.6
1957	92.7	25.02	73.88	98.90	93.7
1958	100.0	25.30	74.70	100.00	100.0
1959	105.9	25.58	75.82	101.40	104.4
1960	109.1	25.88	79.48	105.36	103.6
1961	117.0	27.25	81.57	108.82	107.5
1962	116.3	27.55	83.89	111.44	104.4
1963	115.2	27.88	86.13	114.01	101.0
1964	121.8	28.13	89.27	117.40	103.8
1965	122.5	28.46	93.90	122.36	100.1
1966	127.8	28.79	94.72	123.51	103.5
1967	130.3	29.14	95.76	124.90	104.3
1968	139.2	29.47	97.11	126.58	110.0
1969	142.8	29.78	98.60	128.38	111.2
1970	148.8	30.08	99.87	129.95	114.5
1971	150.6	30.44	101.14	131.58	114.5

$$TPI = \frac{Y}{\alpha N + \rho C}$$

where

TPI = Total productivity index

Y = Output (as a percent of output in some base period).

N = Labor input (as a percent of labor input in some base period).

C = Capital input (as a percent of capital input in some base period).

α = Labor's share of the value of output in the base period.

ρ = Capital's share of the value of output in the base period.

In this case,

$$\rho = \frac{\text{Total return to capital in 1958}}{\text{Value of production in 1958}} = \frac{4991.5}{6678.5} = 0.747$$

$$\alpha = 1.000 - 0.747 = 0.253$$

the output-input ratio. This leads to the question of which are the factors underlying such increases.

Sources of Productivity and Technological Change

In general, the greater levels of total factor productivity achieved in the sector result from several elements among which there should be mentioned: (1) greater development, adaptation of technologies, and the efforts on the part of government and private institutions to improve technology, all of which involves research activities; and (2) the improved extension activities oriented to take new techniques to farmers and make farmers aware of the existence of new techniques and their advantages relative to the old ones, which involves diffusion activities. A quantification of the factors hypothesized to be involved in this process is contained in this section. The factors were: (1) expenditures on research and extension; (2) expenditures on technical assistance; (3) aggregate demand for farm commodities expressed in 1958 pesos; (4) rural education measured as the school completion ratio in rural technical schools; (5) agricultural credit measured as new loans and expressed in 1958 pesos; and, (6) weather, measured as annual variation of overall average precipitation and expressed in index form (1958=100.0).[22]

The above factors were related to the total factor productivity calculated for agriculture. The main results of the estimated relationships are summarized in Table XX.

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[22]See Chapter III, pp. 42-46.

TABLE XX

COLOMBIA: ESTIMATES OF TOTAL PRODUCTIVITY RELATIONSHIPS, 1950-71

Variables	Regression Coefficients and t-Values[a]	
	Equation (1)	Equation (2)
R (Research & Extension)	0.034 (1.902)**	0.036 (2.163)**
T (Technical Assistance)	0.020 (1.440)	
E (Education)	0.555 (3.881)***	0.451 (4.160)***
C (Credit)	0.141 (3.970)***	0.168 (5.695)***
D (Demand)	0.025 (1.654)	0.026 (1.693)
W (Weather)	-0.046 (-0.883)	
Constant Term	1.096	1.153
$\bar{R}^2$	0.956	0.960
SE	0.021	0.021
F-Statistic	82.353	119.522
DW[b]	2.205	1.990

[a]The numbers in parentheses are the t-values. $\bar{R}^2$ is adjusted by degrees of freedom. The variables are expressed in logarithms.

[b]For equation (1) there is evidence of a slight negative autocorrelation since the significant point of the Durbin-Watson statistic is 2.15. For equation (2) the test indicates that there is no autocorrelation (0.01 level of significance).

*Significant at the 0.10 level.

**Significant at the 0.05 level.

***Significant at the 0.01 level.

In Table XX, equation (1) includes all of the variables. However, technical assistance, demand, and weather are statistically insignificant at the 0.10 level. The Durbin-Watson statistic is 2.205, which exceeds the critical level of 2.15 and confirms the presence of negative autocorrelation.

Weather and technical assistance are dropped from the model, resulting in the estimates shown for equation (2). The value of R^2 is slightly higher. All of the remaining variables are statistically significant at least at the 0.10 level, and the Durbin-Watson statistic does not fall outside of the critical bounds. Elimination of technical assistance causes the coefficients for education and farm credit to move in opposite directions due to a negative association with education and a positive association with farm credit, although the association is rather small. The simple correlation coefficients are not large (Table XXI), so multicollinearity is not a major problem. Furthermore, the exclusion of the weather variable does not have much effect on the coefficients, leading to the conclusion that the measure used does not explain in a significant way changes in total productivity.[23]

The coefficients for research and extension, credit and education are statistically significant. As expected from the regression coefficients, the correlation coefficients between productivity and the explanatory variables are higher for research and extension, education and farm credit, and all of them highly significant (Table XXI).

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[23]Even though at the aggregate level the weather variable did not reveal high significance, the sign of the coefficient is of the expected sign. That is, large deviations from average precipitation affect negatively production and productivity in agriculture.

TABLE XXI

SIMPLE CORRELATION COEFFICIENTS AMONG VARIABLES IN THE TOTAL PRODUCTIVITY MODEL FOR COLOMBIA

Variable	Y	R	T	E	C	D	W
Y (Total Productivity)	1.000	--	--	--	--	--	--
R (Research Extension)	0.785	1.000	--	--	--	--	--
T (Technical Assist.)	0.022	0.097	1.000	--	--	--	--
E (Education)	0.921	0.708	-0.258	1.000	--	--	--
C (Credit)	0.927	0.696	0.167	0.795	1.000	--	--
D (Demand)	0.769	0.525	-0.103	0.742	0.663	1.000	--
W (Weather)	0.019	0.237	0.349	-0.068	0.085	-0.028	1.000

The coefficient for research and extension (0.036 in equation (2)) is an indicator of the important role of this factor in influencing the agricultural output-input ratio. A 10 percent increase in expenditures on research and extension is associated with a 0.36 percent increase in the output-input ratio or total productivity in agriculture.

The coefficient estimate for education (0.451) reveals the importance of these programs conducted in rural technical schools. A one percent increase in the ratio as measured by this variable "rural school completion ratio" (relative to total enrollment), is associated with a 0.45 percent increase in productivity. This result is an indicator of the relevance of rural programs of education, including training in farm practices, to enhance agricultural productivity in the country.

Credit also was a significant factor in influencing productivity of the sector. A 10 percent increase in new loans to farm producers results in a 1.68 percent increase of total productivity. The importance of credit as a contributing factor in enhancing farm productivity indicates the role that this factor is to play in the growth of the sector.

The coefficient estimate for the demand variable is rather small (0.026), and not highly significant. The implication is that the aggregate demand for farm products has just a small relevance as a source of productivity and technological change in the agricultural sector. The forces that would cause this factor to be a significant source have not been set in motion in Colombia; consequently, demand is not a very significant factor.

The above results indicate that the major sources of total productivity and further of the technological change in Colombia's agriculture were research and extension, credit and education. The roles played by the other factors were either not as important, or were not correctly specified for the aggregate level.

In the present case, it also is possible to use an approximation equation to account for changes in total productivity during the period 1950-1971. These changes hould be related to changes in the factors considered in the estimation already presented, and the procedure is similar to that used previously in this study. Based on the statistical data presented in Table XX (equation 2), the coefficients used for this purpose are: 0.036 for research and extension, 0.45 for education, 0.168 for credit, and 0.026 for aggregate demand. The approximation equation was:

$$\dot{Y} = 0.036\,\dot{R} + 0.451\,\dot{E} + 0.168\,\dot{C} + 0.026\,\dot{D} + e \qquad (6)$$

where

Y = total factor productivity in agriculture (index, 1958=100),

R = agricultural research and extension (government expenditures in 1958 pesos),

E = rural education (graduates on enrollment ratio in rural technical schools),

C = farm credit (in 1958 pesos), and

D = aggregate farm demand (in 1958 pesos).

The dots refer to annual percentage changes in each factor, and e is the residual to account for other factors and the errors in estimation of parameters.

The results of applying the above equation are presented in Table XXII. The evidence points to farm credit as an important factor explaining productivity growth of agriculture, accounting for 49 percent of the growth. Education played a very important role accounting for 32 percent of productivity growth. Research and extension is next in importance with a contribution of 15 percent to productivity growth. Aggregate demand tended to have a positive effect on productivity, but its effect is rather small.

In summary, agricultural credit, education and research and extension account for most of the increase in measured productivity. There have been some negative effects of other factors that tended to slow down the growth of productivity, hence the negative sign associated with the error term.

As indicated previously, excessively large variations in weather had negative effects on productivity of agriculture. Except for this factor it was not possible to make any quantification of those "other" factors so that they could be incorporated into this analysis. Given their importance as forces that affect productivity growth and the rate of technological change in Colombia's agriculture, a discussion of some of the most important factors involved is presented in Chapter V under the section "Social and Institutional Factors."

TABLE XXII

COLOMBIA: CONTRIBUTION OF SEVERAL FACTORS TO PRODUCTIVITY GROWTH, 1950-1971

Factor	Coefficient $\hat{\beta}$	Annual Change (Percent) $\dot{X}$	Contribution[a] $\hat{\beta}\dot{X}$	Relative Contribution[b]
Research & Extension	0.036	0.0723	0.0026	15.0
Education	0.451	0.0124	0.0056	32.0
Credit	0.168	0.0510	0.0086	49.0
Demand	0.026	0.0720	0.0018	11.0
Other			-0.0012	-7.0
Total Productivity ($\dot{Y}$)		0.0174		

[a]Contribution to change in total productivity as measured by equation (6).

[b]Change in total productivity = 100.0.

CHAPTER V

POLICY IMPLICATIONS

Introduction

The purpose of this chapter is to present the major policy implications that emerge from the study. These policies are based on the empirical results already described, plus the author's knowledge of the economic, cultural, and political conditions of Colombia. The author's value judgements are also included as an inseparable part of policy formulation, but noted where appropriate. Following presentation of the principal policy guides, the practical constraints on implementation are discussed. Having considered potential benefits, costs, and feasibility of alternative policy proposals, a scale of priorities for government action is presented.

Formulation of policies depends on the objectives to be achieved. A policy may be adequate to achieve one objective, but inadequate to achieve another objective. Multiple objectives arise often in the complex field of agricultural policy. In this chapter, six objectives are considered as basic to the agricultural sector:

1. to achieve self-sufficiency,
2. to provide employment for the labor force,
3. to contribute to a favorable balance of payments,
4. to achieve economic efficiency,

5. to provide equity in the distribution of benefits of economic growth, and
6. to enhance the standard of living of population.

The above objectives are self-explanatory and are highly desirable for Colombia's agriculture. It is to note that objective (2) is important in Colombia, given the high rate of population growth, and that objective (5) implies an improvement in the income distribution scheme. These multiple objectives are very useful for the remaining discussion in tnis chapter, since they provide a reference point for policy guides and recommendations.

Allocation and Utilization of Resources

Evidence and Needs for Allocation of Resources Between the Crop and Livestock Sectors

The analysis conducted for the crop and livestock sectors indicated that both subsectors have large potential for production increases. In the crop sector, the degree of returns to scale was estimated to be 1.28, while in the livestock sector, returns to scale were estimated to be 1.73. The basic implication is that the government should stimulate investment in these sectors so that producers could exploit such opportunities for the benefit of the whole society. Formulation of policies designed to create a sound environment for increased investment is not an easy task for the government. Costs, lack of availability of resources, political constraints, and geographic differences are but a few factors that government officials must consider. Some of these factors will be discussed later in the chapter.

For the effective exploitation of the opportunities in agriculture, attention should be given to allocation of resources between the two sectors. The guidepost in this case is the value of marginal product calculated for each factor. The economic rule dictates that maximum production and efficiency is achieved by allocating an input in larger quantities to the sector in which the value of the marginal product of the input is higher. Common resources to both subsectors include land (to some extent), power, and labor.

The value of marginal product of land in crop production in 1970 was estimated at $660.79, while in livestock production it was estimated at only $182.74. If the figures for 1970 are still valid, the net social gain in using additional land in crop production is at least three and a half times higher in crop production than in livestock production.

The value of marginal product of power in crop production in 1970 was estimated at $1.31 per peso spent in the input, while it was estimated at $1.10 for the livestock sector. The implication is that additional allocations of power should be made to the crop sector rather than the livestock sector.

Value of marginal product of labor in the crop sector in 1970 was estimated at $9.81 per man-day, while in the livestock sector was estimated at $9.90. However, the latter includes only hired labor, while the former includes both family labor and hired labor. In both cases, the indication is that labor is overutilized; in general and for the whole period, 1950-1971, the indication is stronger for the livestock sector, while for the crop sector the situation was at about economic equilibrium. The role that agriculture should play in providing employment indicates that labor should be allocated to both sectors. However, it should be noted that the greater employment is at the expense of an increased efficiency, the author's judgement is that these conflicting objectives should be resolved in favor of larger employment to improve the income situation in agriculture. It is estimated that to stabilize the employment situation, the farm sector will have to provide 50,000 new jobs each year from 1970 to 1985, an increase of 1.8 percent annually in employment during that period [10, p. 500].

For purchased inputs, the value of marginal product in crop production in 1970 was estimated at $1.41 per peso spent, while in livestock production was estimated at $1.20 per peso spent on concentrates. These values indicate that purchased inputs should be increased in both subsectors. Competition between the two sectors for this kind of input is not direct since different inputs are required to a large extent, but there is indirect competition for agricultural credit to purchase those inputs.

The above pattern of allocation of resources establishes a scale of priorities for additional availabilities of the inputs. The transfer of existing amounts of resources will also favor an increased production, especially in cases in which there is a large difference between the value of marginal products. This was found to be the situation for land, which will apply to the extent that both sectors use the same kind of land. It is is also to note that allocation to the sector with the higher value of marginal product also reduces inefficiency. Each allocation policy, then, contributes both to maximizing production and to reducing inefficiency. Some examples are given below of policies aimed at achieving the above pattern of allocation of inputs. Limitations are discussed subsequently.

Tax deductions could be implemented for using flat areas as cropped land. The objective is to induce the shift of land from livestock use to crop use.

A lower "presumptive" rent base could be used to tax cropped land, i.e., a productivity tax. The presumptive rent is a rent calculated as a percentage of the market value of the land and which is considered as the rent of that land for taxation purposes. The objective of this policy measure is to encourage the shift of land mentioned above.

A reduction in import taxes should be implemented for importing farm machinery for crop production. The objective of this policy measure is to encourage an increased use of power in crop production.

An expansion of credit is needed to finance purchases of machinery, including imports. Improved machinery and implements are costly for which it is important the provision of financing to producers.

Utilization of Resources Within Sectors

It is important to discuss policies that the government can undertake to promote an expanded and efficient utilization of resources on the part of farmers, especially those resources which have been highly productive in the sector. Purchased inputs, land, and power are inputs for which there are significant potential production gains in the crop sector. The elasticity estimates of 0.100, 0.370 and 0.221, respectively for these inputs indicate that there are significant production response from percentage increases in each of those inputs in the crop sector. Furthermore, it was estimated that for each additional peso spent in purchased inputs in 1970, the total value of crop production increased by $1.41. The corresponding estimates for land and power were $1.89 and $1.31 respectively. The implication is that there are large efficiency gains, and thus production gains to be obtained from expanded use of these inputs.

The situation of labor was found to be about economic equilibrium, but given the need of providing employment, labor utilization should also be encouraged in the crop sector. Some examples of policies aimed at these objectives are presented below.

A progressive tax is needed on uncultivated cropped land, i.e., the larger theuncultivated area, the larger the tax. The objective of this policy measure is to procure an intensive utilization of land and avoid idle land.

A tax deduction is needed to encourage the use of flat areas as cropped land. This policy and those mentioned earlier should induce and encourage an expanded use of land and power in the crop sector.

Increasing the quantity of credit could help finance purchased inputs. This includes consideration of "reasonable" terms and interest rates to charge and flexibility in the credit contract, especially repayment schedules in cases of physical losses due to natural disasters.

Subsidized credit could be made available for acquisition of purchased inputs. This policy refers to institutional credit for small farmers, and involves granting loans at low interest rates.

Provide credit through inputs (credit in kind). This policy should be tied to supervised credit for purchases of inputs to assure the effective utilization of such inputs.

Establish support prices. The support price should be aimed at permitting a favorable relationship between prices of inputs and prices of products. Then, they should be establishing levels high enough to cover production costs and allow a profit margin.

Reduce import taxes for purchases of raw products for domestic production of purchased inputs or for purchases of these inputs directly. Restrictions to this respect constitute serious restraints to increased production and productivity levels. The corresponding situation and policies suggested for livestock production are considered next. Concentrates and livestock capital are inputs for which there are significant potential production gains to be achieved in the livestock sector. The elasticity estimates of 0.037 and 0.505 respectively indicate that there has been significant production response from percentage increases in the use of these inputs in livestock. Also, for 1970, the indication was that for each additional peso spent on concentrates and livestock inventories (livestock capital), value of output increased by $1.20 and $1.78 respectively at the national level. These estimates are signals of the significant potential gains in production and efficiency that can be obtained from expanded utilization of these inputs.

For labor, it was indicated that the movement has been toward equilibrium, and given the need and desired goal of employment provision by agriculture, policies should also be aimed at increasing labor utilization in the livestock sector.

However, increased employment in a situation where labor is already overemployed from an efficiency standpoint indicates a direct conflict between objectives. The expectation is that increased utilization of other inputs through an enlarged investment should facilitate the employment of additional labor in a productive way. In fact, the final outcome depends upon the rate at which investment is increased relative to the rate of increase in labor utilization. The results indicate that the most efficient way to employ labor more productively is not to use more land, but to utilize more animals and feed. That is, for the livestock sector the strategy factors under a policy of job creation are the intermediate inputs, especially feeds and concentrates along with more animals per unit of land. In the livestock sector the expansion of such inputs should be large enough so that family labor as well as additional hired labor can be engaged productively. Some examples of policies aimed at achieving the above objectives are presented below.

Application of a progressive tax on unutilized pasture land is needed, i.e., the larger the unutilized area the larger the tax. The objective with this policy is to enforce use of such lands and increase livestock production in those areas.

An expansion in credit is needed to finance purchase of concentrates and animals. This policy should be aimed at achieving an efficient allocation of credit funds in the livestock sector. The objective should be to procure a modernization of livestock production.

Subsidized credit is needed for purchases of concentrates and animals. This policy measure should be designed especially to small farmers in livestock enterprises.

Credit in kind for the acquisition of concentrates and animals could be initiated. These programs should be of the supervised credit type to assure the effective utilization of such inputs.

Subsidized credit in kind also could be adopted for acquisition of concentrates and improvements of animal inventories. This program, also of the supervised credit type, should be designed to small non-commercial farmers, which are the cases where subsidies can be justified from a social objective standpoint. In these cases of credit in kind, the inputs are to be supplied directly to producers through the credit contract.

A related policy is recommended to avoid reduction of the agricultural land. In this case, land of high agricultural productivity, especially on the Bogota savanna and the flat Cauca Valley should not be allowed to transfer for urbanization. A high tax rate (anti-urban tax) should be imposed on those lands if they shift to urban uses, to avoid the use of those areas for uses other than agriculture.

Another policy, sometimes put into effect in Colombia, is import quotas to encourage domestic production. These regulations should be embraced within a general program of import substitution, which will help improve the balance of payments situation.

Limitations

The policy measures stated above are not always easy to implement or intensify to achieve desired objectives. Some policies exist now, such as provision of general credit and support prices but there are no specific policy programs as those suggested above in the framework and orientation indicated. There are several important limitations to consider, some of which are briefly discussed.

Policy measures involving taxes are not always politically acceptable. Examples are the taxes on uncultivated land and on pasture land not utilized. Frequently, there are strong vested interests associated with those situations which make difficult any change.

The costs in implementing policies can be considered to be of two categories: (a) those costs directly associated with the implementation of policies such as wages, salaries, commitment of financial resources, and (b) the revenue that the government gives up, if any. The expansion of credit, for instance, requires a large amount of scarce financial resources. The lower "presumptive" rent base or productivity tax is an example of (b), where the government incurs a considerable cost due to reduction in fiscal revenue.

There is a lack of a market for increased crop production in the case of several crops, especially those in which consumption is generally adequate. This is the case of corn, kidney beans, non-centrifugal sugar cane (panela), potatoes, cassava, plantains and banana. For these products an increased production is likely to cause significant price reductions at the farm level. A related situation is the general low purchasing power of consumers, which prevents rapid absorption of increased production. Many producers prefer to export products rather than face price decreases, but export markets are not readily accessible, because it takes time to gain international markets. This situation is a limitation for the success of policies aimed at increasing crop production.

Geographical conditions also inhibit success of some agricultural policies, such as policies designed to shift land from livestock production to crop production. There is some scope for policies encouraging that shift in the north and central part of the country, but the case of the eastern plains (los llanos) is quite different. About 12 percent of the total land in the country (about one half of total pasture land), is located in that region, but it has proved to be useful only for livestock farming due to the soil characteristics. In this case, there are few expected benefits from shifting resources into crop production.

A related limitation concerns transportation facilities, which are inadequate in several regions of the country. Increased production does not necessarily reach the market. Producers in that case prefer to produce only for their own consumption and/or for local markets.

The "felt" need for employment of the labor force also limits some policies, mainly those designed to increase the use of machinery in agriculture. Practices involving mechanization will be adopted only by larger farms. These practices will displace labor and are likely to aggravate the social and economic problem of unemployment. For this reason, those measures will not have easy political acceptance in the country.

Some policies are difficult to administer effectively. Examples are the provision of credit in kind, both with and without subsidy. The subsidy scheme to be applied adds even more to administrative difficulties. Also, supervision to assure the effective use of those inputs would be difficult.

The time lag required to realize the full impact of certain policies is another limitation. For instance, taxation of uncultivated lands to induce use has a time lag of at least one year between assessment and payment. Tax evasion is also likely to lessen the impact of such taxes. However, in these cases, it is expected that the higher the tax, the more likely the policy impact will occur rapidly.

The location of many hectares of good agricultural land near large cities is another factor affecting agricultural policies. In fact, conversion of farm land to urban uses has occurred rapidly near large cities such as Bogota, Cali and Medellin. Entrepreneurs have seen a more profitable operation in using those lands for house construction and have purchased the land increasingly for those purposes. Much of that land was previously devoted to livestock farming, and was in the process of a significant shift to crop production due to the competition between the two activities. However, the urbanization process has prevented a further shift. The conflict between the private and social viewpoints is important to be noted. The social cost of those lands would include the "price" of transportation facilities, and availability of other infrastructure capital such as communication and public services. The social cost of the use of those lands for urbanization purposes is not fully reflected in the private costs, so entrepreneurs have found the above operation profitable. Also, the opportunity cost (in the long run) in terms of use of those lands for agricultural production is not reflected in the private costs either. The entrepreneurs in that case have a short run viewpoint, while the social viewpoint leads to long run considerations which dictate the utilization of such lands for agricultural production.

Feasibility and Priorities in Policies

The limitations discussed above give a clear idea of the feasibility of the several policy measures presented previously. To make a presentation in a different and useful framework, Table XXIII presents a ranking of those policies, where policies through import quotas concern conventional inputs. The ranking is made according to two

TABLE XXIII

EVALUATION OF THE CONTRIBUTION AND FEASIBILITY OF ALTERNATIVE AGRICULTURAL POLICIES IN COLOMBIA

	Multiple Objectives							Feasibility						
Policies	Standard of Living	Equity	Economic Efficiency	Balance of Payments	Employment	Self Sufficiency	Total Objectives	Cost	Administrative Demand	Enforcement	Political Acceptance	Time Lag	Total Feasibility	Grand Total
Progressive tax on uncultivated land (cropped land)	2	2	2	0	2	3	(11)	3	2	2	1	2	(10)	[21]
Tax deduction for using cropped land (flat areas)	3	1	2	1	2	3	(12)	1	2	3	3	3	(12)	[24]
Anti-urban tax	2	2	2	0	1	2	(9)	3	2	1	2	2	(10)	[19]
Lower "presumptive" rent base to tax cropped land (Productivity tax)	3	2	2	3	2	3	(15)	1	2	3	3	3	(12)	[27]
Progressive tax on pasture land not utilized	2	3	2	0	2	2	(11)	3	2	1	1	2	(9)	[20]
Import taxes lowered to import machinery (crops)	2	1	3	2	0	2	(10)	2	1	3	3	2	(11)	[21]
Credit to finance purchase of machinery (expansion)	2	1	3	2	0	2	(10)	2	3	3	2	2	(12)	[22]
Credit to finance:														
Purchase of seeds, fertilizers, pesticides (crops)	2	2	3	2	3	3	(15)	2	2	3	3	3	(13)	[28]
Purchase of feed concentrates and animals	2	2	3	2	3	3	(15)	2	2	3	3	2	(12)	[27]
Subsidized Credit (rates&terms)														
Purchase of seeds, fertilizers, pesticides (crops)	3	2	1	2	3	3	(14)	1	2	3	3	2	(11)	[25]
Purchase of feeds concentrates and animals	3	2	1	2	3	3	(14)	1	2	3	3	2	(11)	[25]
Credit to small farmers	3	3	0	0	3	3	(12)	1	2	3	3	2	(11)	[23]
Credit in Kind (Supervised credit)														
Fertilizers, seeds, pest.	2	2	3	2	3	3	(15)	2	1	3	3	2	(11)	[26]
Feeds Con. & animals	2	2	3	2	3	3	(15)	1	0	3	3	2	(9)	[24]
Credit to small farmers	3	3	1	0	3	3	(13)	1	0	3	3	2	(9)	[22]

TABLE XXIII (continued)

Policies	Multiple Objectives							Feasibility						
	Standard of Living	Equity	Economic Efficiency	Balance of Payment	Employment	Self Sufficiency	Total Objectives	Cost	Administrative Demand	Enforcement	Political Acceptance	Time Lag	Total Feasibility	Grand Total
Subsidized credit in kind (lower prices and interest rate)														
Credit to small farmers	3	3	0	0	3	3	(12)	0	1	3	3	2	(9)	[21]
Support Prices (crops)	3	2	2	2	2	3	(14)	1	2	3	3	3	(12)	[26]
Import taxes lowered for purchases of raw products for production of fertilizers, pesticides, or purchased inputs directly	2	0	2	0	2	3	(9)	1	2	3	2	2	(10)	[22]
Import quotas & Import substitution programs	1	1	0	3	2	3	(10)	3	2	3	1	2	(11)	[21]
Rural Education (more people of primary school & training in farm practices)	3	3	3	1	3	3	(16)	0	2	3	2	0	(7)	[23]
Expansion of extension programs (diffusion of technology)(more extension workers & facilities)	3	3	3	1	2	3	(15)	1	2	3	3	1	(10)	[25]
Expansion of agricultural research programs (more research workers & facilities)	3	2	3	3	2	3	(16)	1	2	3	3	1	(10)	[26]
Integration of research and extension workers for demonstration programs to farmers	1	1	1	2	3	3	(11)	1	0	2	3	1	(7)	[18]
Research on crops														
Adaptation of technology (applied research)	3	1	2	3	2	3	(14)	2	3	3	3	2	(13)	[27]
Development of new varieties (basic research)	3	1	2	3	2	3	(14)	1	2	3	3	1	(10)	[24]
Research on livestock														
Breed improvement (basic)	3	1	3	3	3	3	(16)	1	2	3	3	0	(9)	[25]
Feeding & nutrition	3	1	3	2	2	3	(14)	2	2	3	3	2	(12)	[26]
Pasture & management	2	1	3	2	2	3	(13)	2	2	3	3	2	(12)	[25]
Income transfer (to expand demand for farm products)														
Progressive income tax	2	3	3	0	1	1	(10)	3	2	3	2	2	(12)	[22]

TABLE XXIII (continued)

Policies	Multiple Objectives: Standard of Living	Equity	Economic Efficiency	Balance of Payments	Employment	Self Sufficiency	Total Objectives	Feasibility: Cost	Administrative Demand	Enforcement	Political Acceptance	Time Lag	Total Feasibility	Grand Total
Lower Income tax base (In favor of low income families)	3	3	3	0	1	1	(11)	1	2	3	3	2	(11)	[22]
Consumer education and school lunches	2	2	1	1	1	3	(10)	0	1	3	3	1	(8)	[18]
Subsidized food prices to low income families														
Food stamps programs	3	3	1	2	2	3	(14)	1	1	2	2	2	(8)	[22]
Provision in kind at lower prices	3	3	1	2	2	3	(14)	0	1	2	2	2	(7)	[21]

a

( ) means the sum of points of objectives and feasibility respectively.
[ ] means the grand total of both objectives and feasibility.

Multiple Objectives

0 - little of no impact

1 - limited impact

2 - moderate impact

3 - large impact

Feasibility

0 - practically infeasible

1 - could be done with great effort and persistence

2 - moderate difficulty

3 - easily done

Cost

0 - extremely high cost

1 - high cost

2 - moderate cost

3 - low cost

i.e. 0 → bad
.
.
.
3 → best

major criteria: multiple objectives and feasibility. The multiple objectives were already discussed. The factors under feasibility are self-explanatory and some of them were discussed as limitations on policies. The numbers assigned to the policy measures range from 0 to 3, where 0 is always the worst ranking under the respective factor considered, i.e., little or no impact concerning an objective, extremely high cost, very difficult to administer, etc., while 3 is just the opposite; 1 and 2 are intermediate rankings to denote situations such as limited impact and moderate impact respectively, concerning objectives, e.g., high cost and moderate cost.

Given that six objectives are considered, the "ideal" policy under objective would rank 18. Similarly for the five factors considered under feasibility the "ideal" policy under this criterion would have 15 as a ranking. The "ideal" policy under both criteria would have a ranking of 33, indicating high contribution to the objectives and great ease of implementation.

In ranking the several policies, a subjective viewpoint was unavoidable; however, the rankings do represent the actual conditions of the country for each of the respective factors considered, based on previous knowledge. The most promising policies, according to the resulting ranking are those related to credit programs, the lower "presumptive" rent base (productivity tax) and the price support programs. Therefore, considering the limitations for implementation of policies, these policies contribute the most to achievement of the objectives stated previously.

Among the above policies, credit to finance purchases of inputs and price support programs are presently in effect in Colombia. However, credit programs have not put special emphasis on purchases of improved seeds, fertilizers and pesticides for crop production and concentrates and animal inventories for livestock production. The lower presumptive rent base has not been established yet as a policy. There is some regulation for tax purposes only, but indeed, it has been more with the objective of providing fiscal revenue than encouraging agricultural production. Finally, a policy of credit in kind (supervised credit) exists only at a very limited scale for small farmers, but orderly administration of programs has not been established in the country.

In the above evaluation of policies, the objectives were given equal weights, i.e., they were considered equally important. It is possible in the framework used to consider different weights for the objectives, but this would imply knowledge of the "welfare function" of the society. In that case, it is very likely that more subjective considerations are introduced in the analysis.

Policy Implications: Nonconventional Inputs

In this section, the nonconventional inputs included in the study are discussed in a policy-making framework. Also, the major limitations in each case and a suggested priority scale for government action are presented.

Education

Education is measured as the ratio of students who completed primary and technical school to total enrollment in rural schools. The role that education has in productivity growth is substantial. The analytical results indicate that education is a very important force underlying productivity gains in agriculture. A one percent increase in the "rural school completion ratio" is associated with a 0.45 percent increase in total productivity in agriculture, that is, in the output-input ratio.

The benefits that education provides in the case of agriculture, such as better management skills and the ability to understand and use technical information, have occurred to a certain extent in Colombia, but the potential role of this factor is still very large in influencing productivity.[1] The importance of primary school including training in farm practices was revealed in this study. More people in the rural sector need to have primary school training. A key question is what kind of education should be promoted in rural areas. Education, as measured here includes primary education of six years and a technical education on farm cultural practices.

The number of schools with farm training should be expanded in rural areas throughout the country. The program in these schools should strengthen the orientation in primary school and training in farm cultural practices. The educational efforts of SENA in agriculture should be expanded with priority to rural areas.[2] The involvement and direct inclusion of farmers in those programs should be emphasized, especially to help train young people as future farmers. The indication is that the investment made by the government in this field will be more than

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[1]The illiteracy ratio in rural areas estimated for 1970, 41 percent is almost three times as high as in urban zones, and has shown little improvement through time. This variable does not account for children who do not attend school at all.

[2]SENA is Servicio Nacional de Aprendizaje. It is an institute which is in charge of technical and vocational education in agriculture and industrial arts.

compensated by the further productivity growth in agriculture. Government programs should be established that will improve the quality of rural education. Allocation of appropriate budgets including higher salaries to attract good teachers to teach in rural areas should be an essential part of those programs. The major limitations of education programs, however, are the high cost and the long period of time usually necessary to realize the impact of such programs. However, efforts to provide primary education in rural areas should be increased to improve basic abilities of people.

Agricultural Credit

Credit allows farmers to obtain the appropriate quantity of inputs at the right time. It also allows the purchase of a "package" of inputs that will allow production in an efficient way. The credit mechanism is essentially a tool for agricultural development especially in developing countries.

Agricultural credit was found to be a very important factor in enhancing productivity of agriculture. If past experience indicates future trends, a one percent increase in credit will result in a 0.17 percent increase in total agricultural productivity (output-input ratio). New loans to agriculture increased by 184 percent in real terms over the study period, from $340.58 million in 1950 to $531.75 million in 1971, but some factors have prevented credit from playing even a more important role in inducing larger productivity gains. Especially important are: (a) inadequate funds to meet the demand for credit and (b) inequitable distribution of credit as a resource. Credit is available for some regions and products in sufficient amounts relative to requirements. This has been the case of products with some kind of producers' organization which has helped directly in obtaining funds through cooperative arrangements or through pressure on government agencies. Coffee, sugar cane, barley, soybeans, and rice are cases in point. Credit for producers of cotton and irrigated rice accounted for 76 percent of total credit for 12 major crops in 1968. Similarly, about 62 percent of the credit provided by the Agricultural Finance Fund (FFA) was allocated to just three states in 1969: Cesar, Tolima and Valle [47].

The situation in 1971 for credit administered by Caja Agraria indicates that 93 percent of farmers who received credit were small size farmers, and they obtained 62 percent of total credit. The average loan in this group was about $6,700. On the other hand, less than one percent of credit beneficiaries were large size farmers and they obtained 17 percent of total credit. The average loan in this group was $233,231 [57]. Therefore, there is an unequal distribution of credit funds between large-size and small-size producers. Large producers either own the land or have other productive assets to constitute a repayment guarantee, and thus have had easier access to credit. Under these conditions, credit tends to be concentrated which prevents a wider distribution of productivity gains and their benefits.

One means the government is using to meet credit demands of commercial producers is the agricultural finance fund (FFA), which obtains its money from private banks, mainly the central bank. Also law 26 of 1959 requires banks to allocate a certain percentage of their portfolios to agricultural loans. In 1971, the actual figure was 12 percent. This kind of arrangement for credit provision should continue to help finance such producers of cash crops in increasing the contribution to total agricultural production. However, credit provided to small farmers should also be increased according to their needs. Caja Agraria should play a more effective role in this respect with priority to small and medium farmers in the provision of credit while the FFA meets the credit demand from larger, commercial crop producers. Credit facilities should be expanded to allow farmers financing production with emphasis on intermediate inputs such as fertilizers and improved seeds, pesticides and concentrates.

Small farmers should be given special consideration in credit provision to help absorb surplus rural labor. Special credit programs should be devised, including low interest rates and longer terms for loans. Subsidies are likely to be involved, but they can be justified in social terms to help small producers obtain the benefits of credit. In developing countries such as Colombia, farm credit plays a crucial role in productivity growth. It is therefore necessary that the government place more emphasis on an efficient allocation of credit funds by regions and by types of producers.

Credit programs have an advantage over other types of programs in that they have a short-term impact. Their importance as a stimulus in inducing farmers to adopt improved technology is crucial under the current conditions in Colombia, so the government should use that tool as effectively as possible.

Research and Extension

The final non-traditional input identified as highly relevant in influencing total productivity growth in Colombia's agriculture is research and extension. A 10 percent increase in research and extension expenditure will lead to an increase of 0.36 percent in total productivity (output-input ratio). There is some indication that research of medium and long-term nature has a greater effect than current or short-term research on livestock production. The basic research related to improvement of breeds should be a continuous focus of long-term research.

In the short-run the opportunities exist and there is a pool of technical knowledge available for application. In fact what is necessary in the short-run is to induce adoption of present knowledge and techniques such as feeding, nutrition and sanitary practices. This situation suggests that, in the short-run extension programs aimed at adoption of existing technology will have a considerable impact on output and productivity in the livestock sector. These programs should emphasize the technical assistance services to producers to allow more technical and efficient operation of livestock enterprises. For these reasons, extension programs in livestock should have priority over research in the short-run.

For the case of crops, the indication is that research and extension have a considerable impact in both short-term and medium term. A continuous focus of research should be the improvement of varieties for the different crops cultivated in the country. High yielding varieties have been developed for several crops, especially corn, rice, barley and sorghum. The adoption of imported varieties have been successfully undertaken for several products. If past experience indicates future potential, a 10 percent increase in research and extension expenditures will lead to a one percent increase in output. There is a need for further crop research to adapt technology and to find higher yielding varieties and varieties resistant to diseases and pests. These conditions, coupled with the significant effect of those activities on production and total productivity in agriculture require the intensification of research programs.

The movement towards a more productive agriculture through an expanded adoption of technology involving modern inputs will require larger extension efforts from the government to help farmers in selection of seeds, control of pests and diseases, and proper application of fertilizers and chemicals. The Agricultural Institute (ICA) recently has placed special emphasis on the diffusion of technology. It has organized these activities through integrated rural-development programs patterned after the Puebla Project in Mexico, a similar program oriented to raise productivity of small-size farmers. Through 1974, ICA had 22 such projects under way but the availability of trained technicians and extension personnel has been a serious constraint. Also, the inadequate budget allocated to ICA has prevented a more dynamic role. In general, expenditures on research and extension are low in developing countries. Estimates for 1965 indicate that public research expenditures per farm were U.S. $1.50 in South America, while they were U.S. $93 in North America [62, p. 10]. Public research expenditures per farm in Colombia were about U.S. $1.90 in 1965 and U.S. $5.20 in 1970.

The relevance of agricultural research and extension in influencing production and total productivity in the agricultural sector in Colombia is consistent with the findings of other studies on specific commodities recently undertaken in the country. In one of those studies, the internal rate of return of research on rice was estimated to be 53 percent, i.e., rice production had gained on the average 53 cents for each peso invested in research after paying the costs during the period 1957-1971 [3, p. 132]. In another study, the internal rate of return on soybean research in the country was estimated at 79 percent, for the period 1967-1971 [54, p. 77].

In summary, the role of the Agricultural Institute, ICA, in conducting research in agricultural sciences, in monitoring production, in controlling quality of farm inputs, and in developing extension programs all are key factors in raising farm productivity and in accelerating the agricultural development in Colombia. The role of the Institute is becoming even more important for it is now performing functions of agricultural training and education. This latter is closely related to rural education that was found a relevant factor to total productivity growth in agriculture. The Institute should be provided with the necessary funds to perform those functions effectively. The provision of necessary facilities and resources to strengthen the agricultural experiment station system should have top priority in budget allocations for agriculture. Government officials should support and encourage the Institute's programs to the largest extent, so that it can advance and build further the research and extension efforts, for which there are no substitutes in the country as a non-traditional input for productivity growth.

Technical Assistance

Technical assistance, other than extension services, was found unimportant in influencing agricultural productivity. The hypothesis in this case was that these programs are in the group of important non-conventional factors influencing agricultural productivity. The technical assistance programs of the government have been aimed at special campaigns for particular products concerning pests and controls, sanitation programs, and the like. Such programs with a few exceptions are not developed on a systematic and permanent basis despite recent increases in budget allocations.

The provision of technical assistance services needed by farmers is in a transition stage in Colombia. The immediate and less complex services such as selection of plant varieties, simple methods of crop protection and planting methods, are available through the extension programs and are being integrated with the research efforts. However, other services such as application methods and quantity recommendations in fertilization, feeding and nutrition, and farm management assistance are being increasingly provided by the private sector, and are in fact, available to those farmers who can pay for such services. However, the latter kind of services have not been sufficiently used at the aggregate level so as to influence significantly productivity of the whole sector. The government should facilitate the provision of those professional services to farmers. The Agricultural Institute (ICA) should regulate and control these activities in a more intensive way. In addition, the government should induce and encourage further establishment of private firms to provide technical assistance to commercial farmers.[3] By doing so, the government will be able to concentrate more on extension activities and research programs. Important measures such as disease control and quarantine measures should be integrated into the research and extension functions of the government.

Aggregate Demand

The expectation concerning the demand for farm products was that it induces larger productivity gains in agriculture through the response of farmers to an increasing demand. However, this variable was not found important in influencing total productivity change in Colombia's agriculture.

Agriculture tends to be different than industry as to the influence of demand on producers' activities because of different market and marketing conditions involved. Usually, the distribution of farm products is not direct and farmers are not aware of market changes, for instance, consumer preferences. Also, the perishability of many farm products cause special marketing conditions in agriculture. Two major factors are relevant in Colombia with implications for demand for farm products. These are: (1) inefficiencies in the market and (2) the slow expansion of demand.

The inefficiencies in the market do not allow an effective communication system between producers and consumers, where the needs and preferences of the latter are transferred back to the farmer through

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[3]Data are not available to incorporate such factors in a quantitative manner in the context of the present study. Presently it is possible and recommended that evaluation studies be made of private technical assistance to groups of farmers or regions as a basis for the government to effectively supervise and support the adequate provision of such services.

the price system. In particular, for the aggregate farm economy, the evidence indicates that the economic efficiency in the marketing of agricultural products is low [10]. This situation has prevented aggregate demand from playing an important role in affecting technology and productivity growth in agriculture. It is to be expected that as efficiency of the marketing system improves, the role of aggregate demand will become more important. Improvements in the marketing system of farm products are seen as necessary if the increased output made possible by improved technology is to find effective market outlets. The latter is especially important since it constitutes an important incentive to farmers to continue expanding the use of better technology to increase productivity levels.

Another factor that has prevented demand from playing an important role in influencing productivity is the slow expansion of aggregate demand through time. In fact, domestic consumption expressed in 1958 prices has increased by 2.7 percent annually since 1950, which is smaller than the population growth estimated at 3.0 percent annually. Aggregate demand for farm products should grow faster if it is to constitute an effective stimulus for productivity and technological change. Programs of PROEXPO in promoting agricultural exports should be strengthened, mainly for those products in which Colombia is producing a surplus, such as cotton, sugar cane, bananas and tobacco.[4] In the domestic market, the government should apply fiscal and monetary policies aimed at improving the income distribution to produce significant increases in the purchasing power of consumers and increase the

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[4]PROEXPO is the Export Promoting Institute.

effective demand for farm products (see Table XXIII for examples of these policies).

For products consumed by industry, a law should be established enforcing the domestic industry to purchase all local production before any import is allowed, i.e., the imposition of import quotas. Some regulations to this resepct exist for some products, but a law should be promulgated in those terms to assure the market for farm products used by industry. Soybeans, sesame and sorghum producers should benefit from such regulations. The cost situation should be carefully studied in those cases to assure competitive production in the country relative to other countries. Research reveals its importance in this case also, in maintaining and improving the competitive position of traditional and new export products through continuous improvements in technology.

Limitations and Priorities

For non-conventional factors such as those discussed above, there are also limitations to implementation of the suggested policies, which makes important the consideration of feasibility and priorities. Some of the limitations were stated in each case.

Credit programs, as indicated previously, will be costly if they are to be significantly expanded. Even though the impact of credit occurs in a relatively short term, greatly expanded credit may accelerate the rate of inflation in the economy until production is increased.

The major limitation of research and extension programs is the time lag involved for their effects to be felt. This is especially the case with basic research of long-term nature. Also, long-term research programs require large financial resources.

Education programs usually require several years to be implemented; also, their effects are fully realized only in the long-run. Additionally, the expansion and improvement of education programs often demand large financial resources from the government.

Income transfer policies aimed at increasing the demand for farm products frequently do not have easy political acceptance. Also, they are difficult to administer. This kind of limitations severely reduce the feasibility of implementation.

To give a better idea of the impact and feasibility of suggested policies concerning non-conventional factors, a ranking of the policy measures was made with respect to the multiple objectives and feasibility scheme described previously (Table XXIII). Credit is not included in this part, since it was explicitly considered among the policy measures associated with conventional inputs.

The resulting ranking indicates that the most promising policies concern research and extension programs. Included are in order, research on crops with emphasis on adaptation of technology which is essentially applied research, expansion of agricultural research, which implies more research workers and improvement of facilities, research on feeding and nutrition, research on pasture and management, expansion of extension programs which implies more research workers and facilities aimed at diffusion of technology, and research on breed improvement. The categories under research programs are just indicators of the several programs under research activities that may be fruitful to expand. The general conclusion is that, given the limitations on implementation, the greatest effort should be placed on research and extension programs to have the largest total impact on the multiple objectives stated previously.

Social and Institutional Factors

There are some other factors that affect production and productivity in Colombia's agriculture which should be considered for policy purposes. These factors can be grouped in two general categories: social and institutional factors.

One of the major social factors affecting productivity in Colombia's agriculture is the dualism in the agricultural sector; the agricultural sector includes two different producer subsectors. The "modern" subsector is mainly oriented to the production of raw products for industry and export products. This subsector is very modernized with a high level of mechanization, intensive use of fertilizers, improved seeds and feeds, and with relatively high levels of land productivity and high overall productivity. This type of producers are generally medium-size farmers. For instance, Berry [13] stated that farms in the range of 5-50 hectares tended to be the most efficient in 1960. The "traditional" sector, consists mainly of small-size producers (minifundios) oriented to production for the domestic market.

It is characterized by old and traditional techniques of production, high use of labor, a low level of mechanization and, in general, low overall productivity. This dualism in agriculture directly affects the general level of productivity because two opposite forces are affecting productivity levels in Colombia's agriculture. The persistence of small-size farmers which makes uneconomic the use of improved techniques is not expected to have a positive effect on productivity of the whole sector.

Another social factor affecting the level of productivity in the farm sector is the migration of people from rural areas to urban areas. This factor tends to be favorable to the extent that surplus labor exists in rural areas because removal of rural labor leaves more resources per person in agriculture, thus permitting higher levels of productivity on a per-worker basis. Nevertheless, agriculture still has to play an important role as a source of employment in the economy.

Another socio-economic factor affecting productivity is the distribution of resources and the distribution of income in the rural sector. The effect in this case is through the low purchasing power of farmers reflected in purchases of inputs. Certain resources tend to be highly concentrated among a few farmers, which prevents a wider improvement of productivity for more farmers in the farm sector. This has been found to be the case primarily with credit and land among the resources used in the sector.

The present and persistent land tenure structure tends to reduce productivity, since it makes technical progress difficult to attain in the sector. Consequently a real reform of the land tenure situation may be a necessary condition for the technical progress of the farm sector.

The 1970 census data indicates that 72 percent of the farms were less than 10 hectares and they accounted for 6 percent of Colombia's farm land. At the other extreme, less than one-tenth of one percent of farms (just 1,023 farms) had each over 2,500 hectares and comprised about 20 percent of farm land. The same census revealed that 22 percent of farms had less than one hectare and just 0.4 percent of agricultural land. The land distribution pattern is reflected in the income distribution. It is estimated that presently the poorest 50 percent of people engaged in agriculture receive only 16 percent of agricultural income, while the wealthiest 10 percent earn 52 percent of the total agricultural income [46, p. 603].

The total number of farms decreased by 70,170 farms or 5.8 percent between 1960 and 1970, while total farm land increased by 4,144,494 hectares or 15.2 percent. The indication is that a smaller number of farms had more land under control in 1970 relative to 1960. Recent evidence from the 1970 agricultural census indicates that farms over 10 hectares have tended to increase in number as well as in area occupied. Within that group, farms in the 200-1,000 hectare range represented about 20 percent of total farms and they owned about one-fourth of total farm land in 1970. The number of these large farms increased by 20 percent and the area they occupied had a similar increase, 19.8 percent from 1960 to 1970. These figures support further the fact that there is a high and increasing concentration of land in large farms.

Farms in the range of 10-50 hectares also increased in number by 19 percent and in area by about 15 percent between 1960 and 1970. This indicates that some small farms have been consolidated into larger farm units during the period, 1960-1970. Farms smaller than 10 hectares decreased by 11.0 percent in number, and by 5.5 percent in area. This is the only size group that had a decrease during that period.

The unequal distribution of land can be considered as a constraint on agricultural productivity and further on agricultural development. Various reasons account for this constraint. It is expected that the lack of incentive of ownership makes some farmers unwilling to make land improvements and may result in lack of incentives to use improved technology. Also, the ownership pattern is generally perceived to be unfair which tends to cause social tension and political unstability. This in turn results in problems in conducting programs and policies for the sector. Finally, large farms tend to make inefficient use of land and to have a low overall efficiency. Berry [13] presents some evidence to this respect for farms larger than 50 hectares. In turn the small farms find it difficult to adopt rotations, machinery and other modern inputs at a sufficient scale to affect productivity.

The latifundia-minifundia structure which prevails in several areas in the Colombian farm sector prevents production and productivity gains. Plans should be designed to integrate small farms into family farm units. The experiments that INCORA is undertaking in this area should be carefully studied as a basis for expanding similar programs to other areas of the country. Latifundia should be reduced through tax policies of the progressive nature. Regulations to this respect should be effectively applied. Creation of small farm units should be avoided for they have proven to be uneconomic. The author's judgement is that programs designed to aid small farmers, especially farms of less than five hectares are justified more on social than on economic ground, e.g., they may provide equity but not economic efficiency. Farms of medium-size in the range 5-50 hectares have proven to be efficient and the encouragement to this size of farms is justified on economic grounds.

From an institutional viewpoint, several factors affect production and productivity levels. One such factor affecting productivity negatively is the existence of several government agencies attempting to solve rural problems from their respective viewpoints, and without a significant effort to undertake interdisciplinary work. This situation has led to a considerable lack of coordination among these agencies and private agencies dealing with particular crops or particular programs. This situation has made difficult an effective performance of public agencies involved in the farm sector.

Another institutional factor in Colombia affecting the level and changes of farm productivity is the situation of savings and investment in the system. There is no real incentive for saving in Colombia, given the interest rates paid and the rates of inflation. The current rate of interest paid to savings is 16 percent annually, but the current annual rate of inflation is about 28 percent. Under these conditions the real rate of interest for savings is negative, -12 percent annually, which means a considerable disincentive. Only a system that was introduced in the country in 1972 provides a real incentive to saving. The idea with this new system has been to pay a positive real rate of interest by the introduction of a monetary adjustment on a daily basis according to the variations in the general level of prices. However, the problem with this system from the point of view of agricultural productivity has been the use made of the monetary resources obtained. In fact, the system has allowed to induce savings to a significant extent given the incentive provided. But most (if not all) of this money has been used to finance construction and purchase of houses in the country. The result was a considerable and massive demand for those funds, manifested by unprecedented growth in the construction industry. As a result, the agricultural sector has had less monetary resources than previously.

Summary

In this chapter, alternative policies and their limitations have been discussed. Some of the limitations have been particularly inhibiting with respect to agricultural production and productivity. Several factors discussed were the increasing concentration of land and the latifundia-minifundia structure. Also, there has been a slow expansion of demand for farm products, caused mainly by low purchasing power of consumers. This situation calls for income redistribution policies aimed at increasing the effective demand.

Some other factors have played a positive role in influencing agricultural production and productivity. The analysis indicated that physical inputs in which the government should place special emphasis are the intermediate modern inputs -- improved seeds, fertilizers, pesticides, concentrates and feed. Price policies are needed to encourage increased use of these inputs, and an import policy is needed to facilitate the import of those inputs and/or the raw products necessary for domestic production.

Top government priority also should be placed on research and extension programs, and on agricultural credit and rural education programs. The first two factors can be readily effected by government action, i.e., they are effective in the short or medium term. Education programs, however, usually require a long wait before realizing the benefits. For this reason, rural education programs should be considered as permanent programs aimed at improving abilities of rural people in a medium or long term. Agricultural credit, research and extension programs are expected to have more short-term or medium-term impacts and should be considered in this context for policy purposes.

A scheme of multiple objectives and policy feasibility was used to establish priority among alternative government policies. However, most policies are complementary with respect to one or more objectives. The suggestion is that highest priorities should be established for the following programs.

Credit programs are needed to finance purchases of intermediate inputs such as improved seeds, fertilizers, pesticides in the crop sector, and purchases of concentrates and expansion of animal inventories in the livestock sector. Included is supervised credit for provision of such inputs. This latter program should be especially designed for small noncommercial farmers, because if well administered it is an effective way to assure the use of those inputs by such farmers.

A productivity tax should be used. It could be low for the case of crop production (but high for unutilized land) to induce an increased utilization of cropped land and a shift of some good land used in livestock production to crop production.

Support price programs whould be developed aimed at permitting a favorable relationship between prices of purchased inputs and products.

Research and extension programs should be expanded in agriculture, with emphasis on the adaptation of technology and applied research. However, important basic research such as development of new high yielding varieties of crops and breed improvements should be a continuous focus of long-term research and should be encouraged. The extension efforts should be aimed at making farmers confident in, and willing to use, modern technology. Efforts should be made to make small noncommercial farmers aware of new technology and induce them to its use.

Government extension programs have an important role to play in the diffusion of technology efforts.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Reasons for Study and Objectives

Studies on analysis of sources of agricultural production and productivity are especially necessary in developing countries as a basic step in understanding the process of growth in the farm sector and how this growth can be affected by the government. Colombia's agriculture faces different problems such as low production and productivity levels, high unit production costs, small and uneconomic farms, difficulty in securing additional land, difficulty of access to modern inputs, and inadequate markets. All of these problems are related to the first one concerning production or productivity levels, so this is a critical aspect in Colombia's agriculture.

Over one-third of the labor force still earns their livelihood from agriculture, and about 30 percent of the gross domestic product comes from that sector. These factors indicate the importance of agricultural growth in the whole economy and the role of productivity gains. In fact, higher labor productivity will be the basic determinant in the long-run of higher average incomes for the rural people to improve their standard of living.

Land is the basic capital resource for agricultural production. It is estimated that about one-third of total capital investment in

Colombia's agriculture is in land, which makes land productivity gains to be a major concern.

Low agricultural productivity is a serious constraint to the industrialization and economic growth of developing countries. Thus, it is very important to identify the sources of agricultural production and productivity so as to provide increased knowledge for public policy decisions. The main aim of this study was to provide such knowledge from the viewpoint of input utilization and their effects on output for both the crop and livestock sectors. The specific objectives were:

1. To measure the changes in agricultural production and productivity for the crop and livestock sectors during the period, 1950-1971;

2. to identify and estimate the relative importance of the variables that influenced crop and livestock output and productivity for the period 1950-1971;

3. to determine if agricultural inputs were employed at their optimum economic levels at the aggregate level;

4. to determine why inefficiencies existed; and,

5. to formulate aggregate level agricultural policies for future use based upon past experience and potential response in the crop and livestock sectors.

Data referred to are production and input data for the crop and livestock sectors, plus several non-conventional inputs such as research, credit and education. All the data refer to the period 1950-1971 and are national aggregates. Changes were calculated for labor and land productivities and for the index of total productivity for agriculture.

The first approach used the factor share method. This approach indicated that the underlying production function on both the crop and the livestock sectors has remained essentially stable during the period 1950-1971. This, in turn, indicates that the production movements have taken place mostly through movements along the same production function and not through shifts in the aggregate production function.

These results led to the use of a second approach, the production function framework as a meaningful method. Such an approach indicates the underlying production function in each case. The basic model used was the Cobb-Douglas model, which has proven to be a useful analytical device for Colombia's agriculture. Separate estimates are made for the crops and livestock sectors, and for the total productivity model which includes both subsectors.

Results and Implications

The first finding indicated that the production gains which occurred in Colombia's agriculture during the period 1950-1971 were caused primarily by expansion in the use of inputs and very little by efficiency improvements. In fact, for the crop sector, about 95 percent of the increase in output was explained by the increases in inputs, and for the livestock sector about 90 percent of the output increase was explained by expanded input utilization. The above situation indicated that technological change has taken place in a smooth manner without evidence of "technological epochs" in which the input-output relationships changed drastically.

The analysis for crops indicated that quantities of purchased inputs, land, power and labor explain the variations in aggregate crop production adequately according to the statistical tests. Among these, purchased inputs, land and power are the most important variables in influencing crop output, respectively. The greatest potential for obtaining increased value of output from additional units of inputs come mainly from these three inputs. For 1970 it was estimated that one additional peso spent on purchased inputs resulted in an increase of $1.41 on value of crop output; one additional peso spent on the land input led to an increase of $1.89 in crop production value. Finally, one additional peso spent on the power input led to an increase of $1.31 in value of crop output. These figures are signals of too small utilization of these inputs relative to their productivities in crop production. Thus, land, intermediate inputs and power were found to be used below socially recommended levels. Expansion in the use of these inputs would be beneficial to obtain larger output gains in an efficient way.

For land, purchased inputs and power, the tendency is toward a more efficient use in the crop sector, but without reaching socially recommended levels. The figures for 1970 indicate that production opportunities at the aggregate level and efficiency improvements at the aggregate level from the use of these inputs are large.

The crop sector is using about the correct amount of labor under current conditions. Therefore, further productive employment of labor in the crop sector will require the expansion of the resource base relative to labor.

The crop sector was found to be operating under slightly increasing returns to scale, i.e., increases in the use of inputs will lead to at least the same proportional increase in output. The situation indicates that the crop sector has significant economic opportunities to be exploited from the joint expansion of input use.

The use of intermediate purchased inputs and power has been increasing relative to labor and has affected labor productivity positively. Furthermore, research and extension programs have been an important factor in increasing labor productivity in this sector. The physical inputs provided to labor explained 90.5 percent of the total change in labor productivity (output per unit of labor). Technical change explained 9.5 percent of such change, and is a proxy for improvements in education, working conditions and other factors that lead to larger productivity. Labor productivity in the crop sector has increased at a rate of 2.1 percent annually since 1950.

Land productivity has been influenced significantly by the increased use of purchased inputs and power; these inputs are the major factors involved in the gains obtained. Intermediate inputs applied to land have been increasing at a rate of 10 percent per year. This increase in these inputs led to an increase of 0.86 percent in land productivity. Land productivity increased from $1,251 per hectare in 1950 to $1,756 per hectare in 1971, a 40 percent increase, or an increase at a rate of 1.63 percent annually. Similarly, the power input has increased at a rate of about 2.0 percent, and this increase alone increased output by 0.5 percent. Land productivity gains also have been favorably affected by research and extension programs, which have been increasingly provided to the sector. Labor was the least important input in affecting land productivity in crop production.

For the livestock sector the most relevant inputs in influencing production and productivity levels are animal inventories and concentrates and feeds. It was further determined that the livestock sector faces a surplus of labor when total labor engaged in livestock farming is considered. Effective labor hired does have a positive effect on livestock output, but is not as relevant as the other inputs. Land is a dominant input in livestock farming, but considering the marginal additions to output and the cost of the input, there is an excessive amount of land used in livestock production.

For 1970, it was estimated that one additional peso spent on feed concentrates resulted in an increase in output of $1.20; one additional peso spent on livestock inventories increased output by $1.78; and one additional peso spent on the power input increased output by $1.10. These figures suggest low levels of utilization of these categories of inputs relative to their productivities, and that livestock output is not being maximized at the aggregate level. On this basis, the indication is that animal inventories and concentrates, and power to a smaller extent, were found to be used below the socially recommended levels to obtain the largest output gains in an efficient way.

A basic concern is that at the present stage of economic development of Colombia, agriculture still has to play the role of providing an important source of employment because the industrial sector has not expanded enough to absorb the labor surplus from agriculture. Therefore, the livestock sector needs to expand significantly the use of other inputs so as to provide further productive employment. Fortunately, the indication is that the sector faces considerable economic opportunities that are just in the process of being exploited. The potentiality of the sector is large and calls for government action.

The principal guides for action to improve the livestock industry include the inducement of an increase in the stock carrying capacity, i.e., a more intensive utilization of pasture land, and better feeding practices with emphasis on concentrates and improved pastures. There was evidence that the benefits of research and extension are of a long term nature. Thus, long term research projects should be carefully planned to obtain the benefits through time. Examples are the research on development of new breeds, adaptation of foreign breeds to the country, and so forth. The central objective concerning the livestock sector should be to secure application of present knowledge and techniques to the maximum scale possible. A special emphasis on extension programs aimed to that objective is desirable under the present conditions of the sector. Research of a short-term nature that should be beneficial includes pasture management, development of new and improved varieties of pasture, and feeding and nutrition.

The government should induce the most effective allocation of resources between the crops and livestock sectors given that they compete for some common resources. Land and power were found to have more potential for output increases in the crop sector than in the livestock sector. The case of land is particularly important. The estimates for 1970 indicate that the increase in output in crop production is at least three and a half times as high as in livestock production for eacn additional hectare of land used. Land and power are scarce resources in agriculture and their allocation should be made with priority to crops, to obtain the larger benefits through output increases.

The importance found for intermediate modern inputs, i.e., improved seeds, fertilizers, pesticides and feeds, indicate that the movement towards a progressive and fast growing Colombian agriculture is dependent on the expansion in the use of these inputs. The provision of incentives to farmers to induce them to use larger quantities of those inputs is crucial under the current conditions in the country. Farmers need to be shown the profitability of those intermediate inputs, and the conditions for that situation to exist should be sought by the government through adequate price support policies. A related difficulty is the availability of raw products for the domestic production of those inputs to assure their availability to farmers. These conditions along with the marketing and distribution conditions of those intermediate modern inputs should be improved to accelerate the growth of agriculture. Colombia's agricultural production and productivity would have been larger than it has been in recent years if these modern inputs had been provided to farmers in more abundant quantities.

A total productivity index was estimated as an indicator of the efficiency gains in the use of labor and capital in agriculture. The sources that underlie changes in the index were categorized as non-conventional inputs. The relevant sources of total productivity growth in Colombia's agriculture were rural education, agricultural credit and research and extension.

Education has an important role, the indication being that doubling the level of rural education (measured as the school completion ratio in rural schools) will lead to a 50 percent increase in total productivity in agriculture. For the aggregate farm economy this would be a tremendous productivity gain for it has taken over twenty years since 1950 for total productivity of the sector to increase by 45 percent.

Rural education programs are highly beneficial for productivity growth in the sector.

The significance of agricultural credit suggests that the provision of rural credit is important to achieve productivity gains and the development of agriculture. The acquisition of modern inputs depends heavily on the availability of credit. In general, the only way Colombia's farmers can obtain those inputs in adequate quantities and at the right time is by the use of credit. Small farmers have had little access to credit and need special credit programs.

The significance of agricultural research and extension suggests the importance of this non-conventional input to improve productivity and technological change in agriculture. The evidence is also supported by other related research that has estimated considerable internal rates of return for agricultural research in individual crops.

Demand for agricultural products was not proven as a relevant factor affecting technological change in agriculture. Associated factors are the lack of an efficient marketing system for farm products, the low per capita income, and the uneven income distribution among Colombian people. The results have been a very slow expansion in demand, and its subsequent small role in inducing technological change in agriculture.

There are serious limitations on effective government action in agriculture, mainly due to scarce financial resources to undertake and/or expand programs. For this reason, the ranking of priorities is a major concern of policy decision makers. Given these considerations, a scheme of multiple objectives and policy feasibility was used to establish priorities among alternative government policies. The conclusions are that priorities should be concentrated in: (1) credit programs to finance purchases of intermediate inputs such as improved seeds, fertilizers, pesticides in the crop sector and purchases of concentrates and animal inventories in the livestock sector. Included is credit in kind in which inputs are provided directly to farmers through supervised credit. This latter program should be especially designed for small non-commercial farmers; (2) a productivity tax, especially low for the case of crop production but high for unutilized land. Special consideration should be given to land areas near consumption centers to induce an increased use of such areas and shift of level fertile land used in livestock production to crop production; (3) price support programs, which should be aimed at permitting a favorable relationship between prices of purchased inputs and product prices; and (4) research and extension programs in agriculture, with emphasis on adaptation of technology and applied research.

Limitations and Suggestions for Future Research

The major limitation of the study concerned the data available for analysis. Data availability is always a problem in Colombia for conducting research, especially economic research. This situation resulted in much emphasis on the data collecting work. A special effort was made to use the source most related to the specific information to be obtained in each case. However, there are deficiencies in the data collecting system in Colombia, including lack of sufficient management level personnel trained for these purposes and not enough field workers.

Some more recent tendencies and policies for agriculture may inhibit the validity of the results and implications of this study for later years. Nevertheless, the basic economic forces and the structure of the farm economy have not changed much in the last four or five years. For this reason, it is considered that the basic pattern identified for Colombia's agriculture in the framework of this study holds for the immediate future.

The CES model is a model that can be employed in future research incorporating more specifically study of the technological change in the sector. Some research along these lines using cross sectional data throughout the country may be useful. The use of census data should be explored for these purposes. A further research need is the exploration of the complementarity among factors of production and between conventional inputs and non-conventional inputs. Studies of this kind will help government decisions concerning inducement in utilization of inputs.

Some studies at a smaller degree of aggregation should provide useful knowledge in the further analysis of production and productivity changes. Studies at the regional level with consideration of the impact on employment and income in the rural community will be useful in this framework.

At the national level, an input-output model, with special consideration of the agricultural sector, should prove useful. Some initial stages have been taken in this direction but it is important to involve more intensively research people and government agencies around the development of such a model. Such efforts can help improve data quality and availability in agriculture.

Given the financial and technical personnel limitations in Colombia, the government agencies in charge of research and action programs in agriculture should put special emphasis in developing better data along with the research and action programs being undertaken. Improved data will facilitate further research to provide a base for sound policy formulations and adjustments in policies for agriculture. Such policy formulations are a special need for agriculture to accelerate its growth and contribute effectively to the economic development of the country.

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APPENDIX A

THE FACTOR SHARE APPROACH

Technological Change

Direct estimation of technological change is very difficult. The number of patents granted are sometimes used as a rough measure of technological change or an important component thereof [70, p. 10]. However, there are substantial differences in market structure, features of the product, costs and other factors involved which cause difficulties for aggregation and comparison purposes. Besides, this procedure is not applicable to the case of agriculture with relatively free choice of enterprises and techniques to apply without direct government control. Another commonly used method is to look at changes in the production function and associate them with technological change, that is, to measure productivity changes as a proxy for technological changes in the industry under study.

Solow's [84] approach allows the calculation of an expression of technological change. If technological progress is only of the neutral type, the production function can be written as:

$$Y = A(t) f(C, N) \qquad (1)$$

where the multiplicative factor A (t) measures the accumulated effect on shifts in the production function through time. It is a measure of the output expansion not due to expansion of capital (C) and labor (N). In this sense, A_t is considered to measure the technological change. As an intercept in the function, A_t will be measured in the same units of output (Y). However, since the interest lies on changes, the focus is the change in A_t, say ΔA_t. The proportional change in A_t is what is referred to as a measure of technological change in this approach, and is to be derived below.

Taking the total differential of (1) with respect to time:

$$\frac{dY}{dt} = A(t)\left(\frac{\partial f}{\partial C}\frac{dC}{dt} + \frac{\partial f}{\partial N}\frac{dN}{dt}\right) + f(C,N)\frac{d\,A(t)}{dt}$$

Dividing by Y, we have

$$\frac{\frac{dY}{dt}}{Y} = A(t)\,\frac{1}{Y}\frac{\partial f}{\partial C}\frac{dC}{dt} + A(t)\,\frac{1}{Y}\frac{\partial f}{\partial N}\frac{dN}{dt} + \frac{d\,A(t)}{dt}\,\frac{1}{A(t)}$$

Denoting

$$\frac{dY}{dt} = \dot{Y}$$

$$\frac{dC}{dt} = \dot{C}$$

$$\frac{dN}{dt} = \dot{N}$$

$$\frac{d\,A(t)}{dt} = \dot{A}$$

and A for A_t we have

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + A\,\frac{\partial f}{\partial C}\frac{\dot{C}}{Y} + \frac{\partial f}{\partial N}\frac{\dot{N}}{Y} \qquad (2)$$

Multiplying and dividing the second term of the right hand side by C and the third term by N, we have

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + A\,\frac{\partial f}{\partial C}\frac{C}{Y}\frac{\dot{C}}{C} + A\,\frac{\partial f}{\partial N}\frac{N}{Y}\frac{\dot{N}}{N} \qquad (3)$$

but it can be seen from (1) that

$$\frac{\partial Y}{\partial C} = A\,\frac{\partial f}{\partial C}$$

$$\frac{\partial Y}{\partial N} = A\,\frac{\partial f}{\partial N}$$

using these expressions in (3), we have

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{\partial Y}{\partial C}\frac{C}{Y}\frac{\dot{C}}{C} + \frac{\partial Y}{\partial N}\frac{N}{Y}\frac{\dot{N}}{N} \tag{4}$$

Let us define

$$\frac{\partial Y}{\partial C}\frac{C}{Y} = \frac{r}{p}\frac{C}{Y} = W_C = \text{share of capital}$$

$$\frac{\partial Y}{\partial N}\frac{N}{Y} = \frac{w}{p}\frac{N}{Y} = W_N = \text{share of labor}$$

which is the case in equilibrium, when factors are paid their marginal products, where

r = rental value per unit of capital,

w = wage rent, and

p = price of product.

Replacing W_N and W_C in (4)

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + W_C\frac{\dot{C}}{C} + W_N\frac{\dot{N}}{N} \tag{5}$$

This expression can be written:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + W_C\frac{\Delta C}{C} + W_N\frac{\Delta N}{N} \tag{6}$$

Where the Δ's are the discrete approximations to the derivatives with respect to time.

$\frac{\Delta A}{A}$ is the expression for technological change, that is

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - W_C\frac{\Delta C}{C} - W_N\frac{\Delta N}{N} \tag{7}$$

Expression [7] is the total factor productivity index of Abromovitz type [1]. This was the first researcher to give the name of residual to such an expression. The validity of this expression only requires that the production function be homogeneous. In this study, expression (7) will be evaluated and an index of technological change, A(t), of the type suggested by Solow will be obtained as follows:

Arbitrarily set A1951 = 1.000

then

$$At + 1 = At + \Delta At$$

$$At + 1 = At + \frac{\Delta At}{At} At$$

$$At + 1 = At \left(1 + \frac{\Delta At}{At}\right)$$

Since $\frac{\Delta At}{At}$ values are known from (7) and At is set as A1951 = 1.000, the whole series for At can be obtained. In this study, expression (7) was evaluated for crops and livestock. Capital input was further dissaggregated as indicated in Tables XXIV and XXV. The results indicate that most of expansion in output was due to expanded use of inputs and very little by total factor productivity or efficiency gains from improved technology. In the crop sector, about 95 percent of output increase was explained by increased inputs, and for the livestock sector about 90 percent of output increase was explained by expanded input utilization during the period, 1950-1971. The trends from the 1950's to the 1960's indicate that both sectors have gained in efficiency improvements to some extent. The crop sector had positive gains in the 1960's, while it had negative gains on the average in the 1950's. The livestock sector had even larger positive gains in the 1960's which indicates a considerable recovery of this sector in the 1960's compared to the 1950's.

Index of Technological Change in the Crop Sector

The expression labeled At provides an indicator of technological change for the crop sector. The values for $\frac{\Delta At}{At}$ and the At series for the period, 1950-1971 are presented in Table XXVI. At is an approximation for technological change in index form for the crop sector.

The calculated index of technological change for the crop sector increased by 8.7 percent during the period 1950-1971. The annual change in this index does not show a definite pattern, being positive for 11 of the twenty-one years in the series and negative for the remaining 10 years. The average rate of change of At was 0.64 percent annually. Thus, the technological change for the crop sector in the aggregate does not appear to have been very significant throughout the period analyzed. The index indicated an increasing trend, even of slight magnitude, for the 1958-1962 period. Modernization of the sector occurred during that period and some new crops began to be cultivated on a commercial basis such as soybeans and sorghum. Other crops such as cotton, sugarcane and rice also entered in a period of modernized methods of cultivation and rapid increases in production. Export surpluses were generated for these products during that period at a rapid rate. However, the technological change for the aggregate crop sector was rather slow. The major crops with tendencies to be produced on a commercial basis by the use of new technologies have a minor effect on technological change of the whole sector. Crops produced by traditional methods of cultivation and on a semi-commercial basis had a greater impact on the aggregate level of technological change of the sector.

Index of Technological Change in the Livestock Sector

The technological change index for the livestock sector increased by 8.1 percent during the whole period 1950-1971, that is, it increased slightly less than the corresponding index for the crop sector. The annual changes in the index were positive for 13 years and negative for eight years in the series, which indicates the lack of a definite trend in the index. The average rate of change of the index was just 0.55 percent annually (Table XXVII). Similar to the crop sector, the technological change for the livestock sector in the aggregate has not been very significant throughout the period considered. There have been some technological improvements in beef cattle producing subsector but the backward technology state of a large number of ranches in this group and the other livestock producing subsectors influence negatively the technological index of the aggregate livestock sector.

TABLE XXIV

COLOMBIA: CROP OUTPUT AND INPUT AND TOTAL FACTOR PRODUCTIVITY, 1950-1971[a]

Category of Input	1958 Input Share (Percent)	Rates of Change in Inputs (Percent)			Rates of Change in the Input's Contribution to Output (Percent)		
		1950-1960	1960-1971	1950-1971	1950-1960	1960-1971	1950-1971
Purchased Inputs	12.0	6.20	5.00	5.57	0.74	0.60	0.66
Power and Implements	42.1	8.54	0.42	4.28	3.59	0.17	1.80
Land	15.0	2.30	0.91	1.57	0.34	0.13	0.23
Labor	30.9	1.03	1.22	1.13	0.31	0.37	0.34
Total Input	100.0				4.98	1.27	3.03
Total Factor Productivity					-0.58	0.83	0.17
Total Output					4.40	2.10	3.20

[a]The rates of change are compound rates of change calculated for the terminal years. The rate for 1960-1971 is weighted average of those for 1950-1960 and 1961-1971.

TABLE XXV

COLOMBIA: LIVESTOCK OUTPUT AND INPUT AND TOTAL FACTOR PRODUCTIVITY, 1950-1971[a]

Category of Input	1958 Input Share (Percent)	Rates of Change in Inputs (Percent)			Rates of Change in the Input's Contribution to Output (Percent)		
		1950-1960	1960-1971	1950-1971	1950-1960	1960-1971	1950-1971
Concentrates	2.00	97.20	15.56	55.00	1.94	0.31	1.10
Land	35.00	0.75	1.91	1.36	0.26	0.67	0.48
Livestock Capital	37.00	-0.18	3.59	1.80	-0.06	1.33	0.67
Power	4.00	6.64	2.30	4.36	0.26	0.09	0.17
Labor	22.00	0.40	2.18	1.33	0.08	0.48	0.29
Total Input	100.00				2.48	2.88	2.71
Total Factor Productivity					0.43	1.26	0.51
Total Output					2.91	4.14	3.22

[a]The rates of change are compound annual rates of change calculated for the terminal years. The rate for 1950-1971, is a weighted average of the rates for 1950-1960 and 1960-1971.

TABLE XXVI

COLOMBIA: INDEX OF TECHNOLOGICAL CHANGE IN THE CROP SECTOR, 1951-1971

Year	$\frac{\Delta At}{At}$	At
1951	-0.088	1.000
1952	0.090	0.912
1953	0.013	0.994
1954	0.069	1.007
1955	-0.131	1.076
1956	-0.015	0.935
1957	-0.082	0.921
1958	0.124	0.846
1959	0.048	0.950
1960	-0.021	0.996
1961	0.043	0.975
1962	-0.066	1.017
1963	-0.004	0.950
1964	0.026	0.946
1965	-0.008	0.971
1966	0.093	0.963
1967	0.001	1.053
1968	0.075	1.054
1969	-0.055	1.133
1970	0.015	1.071
1971	-0.022	1.087

TABLE XXVII

COLOMBIA: INDEX OF TECHNOLOGICAL CHANGE IN THE LIVESTOCK SECTOR, 1951-1971

Year	$\frac{\Delta At}{At}$	At
1951	-0.0870	1.000
1952	-0.0215	0.913
1953	-0.0205	0.893
1954	0.0050	0.875
1955	0.0364	0.879
1956	-0.0680	0.911
1957	0.0353	0.849
1958	0.0220	0.879
1959	0.0211	0.898
1960	0.0513	0.917
1961	-0.0098	0.964
1962	0.0211	0.954
1963	0.0165	0.975
1964	0.0342	0.991
1965	-0.0019	1.025
1966	-0.0138	1.023
1967	0.0244	1.009
1968	0.0253	1.033
1969	0.0340	1.059
1970	-0.0126	1.095
1971	0.0252	1.081

APPENDIX B

DURBIN'S METHOD OF ESTIMATION

This method has been suggested in the context of time series regression models. Consider the model:

$$Y_t = \alpha + \beta X_t + \varepsilon_t \tag{1}$$

$$Y_{t-1} = \alpha + \beta X_{t-1} + \varepsilon_{t-1} \tag{2}$$

Multiply (2) by ρ, correlation measure of ε_t and ε_{t-1}

$$Y_t - \rho Y_{t-1} = \alpha(1-\rho) + \beta(X_t - \rho X_{t-1}) + (\varepsilon_t - \varepsilon_{t-1}) \tag{3}$$

But,

$$\varepsilon_t = \rho\varepsilon_{t-1} + U_t$$

$$\varepsilon_t - \rho\varepsilon_{t-1} = U_t$$

under a first autoregressive scheme, we can write,

$$Y_t - \rho Y_{t-1} = \alpha(1-\rho) + \beta(X_t - \rho X_{t-1}) + U_t \quad (t=2,3,...n) \tag{4}$$

Two steps are involved in the estimation procedure.

First, rewrite (4) as:

$$Y_t = \alpha(1-\rho) + \rho(Y_{t-1}) + X_t - \beta\rho(X_{t-1}) + U_t$$

or

$$Y_t = \alpha^* + \rho Y_{t-1} + \beta X_t + \gamma X_{t-1} + U_t \tag{5}$$

This is a regression equation with Y_{t-1}, X_{t-1} and X_t as explanatory variables, and can be estimated by ordinary least squares. The estimate of ρ, say $\hat{\rho}$ is used to construct new variables.

These new variables are:

$(Y_t - \hat{\rho}Y_{t-1})$ and $(X_t - \hat{\rho}X_{t-1})$

Now, it is necessary to estimate:

$$(Y_t - \hat{\rho}Y_{t-1}) = \alpha^* + \beta(X_t - \rho X_{t-1}) + U_t \tag{6}$$

where

$$\alpha^* = \alpha(1 - \hat{\rho})$$

The estimators of α and β that we get will have the same asymptotic properties as the maximum likelihood estimators. α can be estimated as:

$$\alpha = \frac{\alpha^*}{(1 - \hat{\rho})}$$

For K independent variables, in the two stage estimation procedure, we will have:

$$Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \dots + \beta_{kt} + \varepsilon_t \qquad (7)$$

and from (7),

$$Y_t = \alpha^* + \rho Y_{t-1} + \beta_1 X_{1t} + \alpha_1 X_{1t-1} + \beta_2 X_{2t} + \alpha_2 X_{2t-1}$$
$$+ \beta_3 X_{3t} + \alpha_3 X_{3t-1} + \dots + \beta_k X_{kt} + \alpha_k X_{kt-1} \qquad (8)$$

Equation (8) can be estimated by ordinary least squares to get $\hat{\rho}$.

Now, we can write:

$$(Y_t - \hat{\rho} Y_{t-1}) = \alpha^* + \beta_1 (X_{1t} - \hat{\rho} X_{1t-1}) + \beta_2 (X_{2t} - \hat{\rho} X_{2t-1})$$
$$+ \beta_3 (X_{3t} - \hat{\rho} X_{3t-1}) + \dots + \beta_k (X_{kt} - \hat{\rho} X_{kt-1})$$
$$+ U_t \qquad (9)$$

where

$$\alpha^* = \alpha(1 - \hat{\rho})$$

Finally, equation (9) can be estimated to get $\hat{\hat{\alpha}}$ and $\hat{\hat{\beta}}$ (2nd round).

APPENDIX C

SELECTED DATA

TABLE XXVIII

COLOMBIA: CROP AND LIVESTOCK PRODUCTION, 1950-1971

Year	Crop	Livestock
	(million of 1958 pesos)	
1950	3,013.2	2,167.8
1951	3,144.1	1,881.6
1952	3,728.5	1,930.7
1953	3,603.1	1,924.3
1954	3,860.6	1,980.4
1955	3,777.7	2,220.5
1956	3,923.2	2,336.2
1957	3,824.9	2,440.4
1958	4,239.1	2,510.6
1959	4,534.0	2,560.9
1960	4,647.5	2,703.0
1961	5,070.0	2,762.0
1962	4,899.8	2,918.7
1963	4,716.0	3,134.0
1964	5,023.8	3,187.7
1965	5,018.9	3,198.9
1966	5,343.6	3,207.2
1967	5,337.2	3,417.0
1968	5,749.2	3,580.5
1969	5,736.4	3,821.2
1970	5,960.7	4,020.6
1971	5,868.3	4,319.4

Source: Instituto Colombiano Agropecuario, ICA, "Resena de Estadisticas Aeropecuarias en Colombia, 1950-1971" [57].

TABLE XXIX

COLOMBIA: CROPPED LAND AND PASTURELAND, 1950-1971

Year	Cropped Land	Pastureland
	(million hectares)	
1950	2.4096	16.1431
1951	2.6301	16.2001
1952	2.7784	16.2025
1953	2.7877	16.4423
1954	2.9273	16.5002
1955	3.0566	16.6281
1956	2.9499	16.7565
1957	2.7992	16.8808
1958	2.8619	16.9477
1959	2.9574	17.0330
1960	2.0237	17.3889
1961	3.0195	17.6476
1962	3.1128	17.9517
1963	3.0558	18.0904
1964	3.2422	18.2116
1965	3.4014	18.4716
1966	3.4589	18.5970
1967	3.3903	18.9893
1968	3.3971	19.5652
1969	3.3860	20.3369
1970	3.3376	20.9010
1971	3.3418	21.4097

Source: Instituto Colombiano Aeropecuario, ICA, "Resena de Estadisticas Aeropecuarias, 1950-1971" [57] for cropped land. Departamento Administrativo Nacional de Estadistica, Boletin Mensual de Estadistica No. 253-254 [31] for pastureland.

TABLE XXX

COLOMBIA: INDEX OF PURCHASED INPUTS IN CROP PRODUCTION, 1950-1971[a]

Year	Index (1958 = 100)
1950	26.8
1951	34.2
1952	31.1
1953	34.1
1954	64.5
1955	60.0
1956	76.2
1957	91.9
1958	100.0
1959	135.3
1960	123.7
1961	148.8
1962	175.0
1963	159.0
1964	190.4
1965	187.0
1966	244.7
1967	284.1
1968	305.9
1969	270.6
1970	267.0
1971	288.2

[a]Average index of improved seeds, fertilizers and pesticides used in crop production.

Source: Instituto Colombiano Agropecuario, ICA. "Resena de Estadisticas en Colombia, 1950-1971" [57].

TABLE XXXI

COLOMBIA: LABOR EMPLOYED IN CROP AND LIVESTOCK SECTORS, 1950-1971[a]

Year	Crop	Livestock
	(thousands of man-years)	
1950	1,245.0	331.0
1951	1,253.0	333.0
1952	1,252.0	333.0
1953	1,252.0	333.0
1954	1,252.0	336.0
1955	1,265.0	340.0
1956	1,279.0	344.0
1957	1,293.0	348.0
1958	1,307.0	352.0
1959	1,322.0	357.0
1960	1,380.0	332.0
1961	1,453.0	350.0
1962	1,469.0	354.0
1963	1,486.0	358.0
1964	1,501.0	361.0
1965	1,518.0	366.0
1966	1,536.0	370.0
1967	1,555.0	374.0
1968	1,572.0	378.0
1969	1,588.0	382.0
1970	1,558.0	432.0
1971	1,577.0	437.0

[a]Data developed from Departamento Administrativo Nacional de Estadistica - DANE. Boletin Mensual de Estadistica No. 277, Bogota (August, 1974). On the basis of these estimates, total labor force was estimated to be distributed between the crop and livestock sectors, as follows: 1950-1959 - 79 percent in the crop sector, 21 percent in the livestock sector;
1960-1969 - 80.6 percent in the crop sector, 19.4 percent in the livestock sector;
1970-1979 - 78.3 percent in the crop sector, 21.7 percent in the livestock sector.

TABLE XXXII

COLOMBIA: WAGE BILL IN THE LIVESTOCK SECTOR, 1950-1971[a]

Year	Livestock
	(millions of 1958 pesos)
1950	394.1
1951	418.2
1952	375.8
1953	392.9
1954	412.4
1955	430.6
1956	405.0
1957	415.5
1958	393.5
1959	440.7
1960	425.5
1961	472.4
1962	499.8
1963	531.8
1964	554.1
1965	532.9
1966	568.9
1967	533.0
1968	508.0
1969	597.1
1970	622.3
1971	622.4

[a]Data developed from Departamento Administrativo Nacional de Estadistica - DANE, Boletin Mensual de Estadistica No. 276. Nominal wages were deflated by the index of implicit prices of the gross domestic product reported by Banco de la Republica in national accounts.

TABLE XXXIII

COLOMBIA: CONCENTRATES USED IN LIVESTOCK PRODUCTION, 1950-1971

Year	Livestock
	(thousands of tons)
1950	.278
1951	.278
1952	.243
1953	.721
1954	3.433
1955	3.500
1956	72.756
1957	68.175
1958	73.735
1959	102.124
1960	125.275
1961	166.457
1962	186.871
1963	255.821
1964	229.233
1965	216.190
1966	321.785
1967	401.168
1968	391.376
1969	452.254
1970	563.228
1971	614.702

Source: Instituto Colombiano Agropecuario ICA "Resena de Estadisticas Agropecuarias en Colombia, 1950-1971" [57].

TABLE XXXIV

COLOMBIA: LIVESTOCK CAPITAL, 1950-1971[a]

Year	Livestock
	(millions of 1958 pesos)
1950	823.46
1951	833.31
1952	810.32
1953	793.90
1954	781.60
1955	781.60
1956	803.75
1957	814.43
1958	821.00
1959	829.21
1960	808.68
1961	865.33
1962	891.60
1963	914.59
1964	937.58
1965	958.10
1966	982.73
1967	1,018.04
1968	1,061.55
1969	1,109.17
1970	1,148.57
1971	1,192.10

[a]Interest charges on valuation of animal inventories. Data on value obtained from Banco de la Republica, Registros de Cuentas Nacionales. The interest rates applied were the average rates charged by Caja Agraria for agricultural loans during the period 1950-1971; 11.4 percent during the period 1950-1954, 11.2 percent during the period 1955-1959, 11.6 percent during the period 1960-1964, and 12.3 percent during the period 1965-1971.

TABLE XXXV

COLOMBIA: GOVERNMENT EXPENDITURES ON AGRICULTURAL RESEARCH AND EXTENSION, 1950-1971

Year	Expenditures
	(million of 1958 pesos)
1950	10.7
1951	12.9
1952	14.8
1953	14.9
1954	12.3
1955	14.0
1956	21.4
1957	16.2
1958	20.0
1959	20.1
1960	19.9
1961	22.5
1962	19.7
1963	12.1
1964	14.0
1965	18.8
1966	16.0
1967	24.9
1968	33.4
1969	39.6
1970	44.2
1971	46.4

Source: Ministerio de Hacienda, Presupuestos Nacionales, Fiscal years 1950-1971 [75].

TABLE XXXVI

COLOMBIA: GOVERNMENT EXPENDITURES ON AGRICULTURAL TECHNICAL ASSISTANCE, 1950-1971

Year	Expenditures
	(million of 1958 pesos)
1950	3.9
1951	3.9
1952	7.8
1953	4.8
1954	11.5
1955	11.6
1956	4.2
1957	3.1
1958	2.4
1959	2.1
1960	2.7
1961	8.6
1962	8.2
1963	3.7
1964	2.6
1965	5.5
1966	4.8
1967	4.3
1968	7.2
1969	6.0
1970	5.2
1971	6.0

Source: Ministerio de Hacienda. Presupuestos Nacionales, Fiscal years 1950-1971 [75].

TABLE XXXVII

COLOMBIA: AGRICULTURAL CREDIT, 1950-1971[a]
(NEW LOANS)

Year	New Loans
	(million of 1958 pesos)
1950	592.5
1951	650.6
1952	879.0
1953	946.6
1954	1,173.9
1955	1,275.0
1956	1,239.0
1957	1,061.0
1958	1,097.1
1959	1,287.0
1960	1,099.8
1961	1,325.8
1962	1,349.1
1963	1,381.5
1964	1,510.3
1965	1,186.3
1966	1,346.3
1967	1,442.8
1968	1,583.9
1969	1,735.4
1970	1,717.4
1971	1,684.4

[a]The sum of new loans of commercial banks and the Rural Bank (Caja Agraria). For commercial banks loans data were obtained from Banco de la Republica [9]. For Caja Agraria loans data were obtained from Caja Agraria, Informe Anual del Cerente [21].

TABLE XXXVIII

COLUMBIA: RATIO OF RURAL EDUCATION, 1950-1971[a]

Year	
1950	64.0
1951	65.0
1952	66.0
1953	67.0
1954	69.0
1955	70.0
1956	72.0
1957	73.0
1958	78.0
1959	85.0
1960	83.0
1961	76.0
1962	79.0
1963	73.0
1964	79.0
1965	75.9
1966	79.0
1967	79.0
1968	80.0
1969	81.0
1970	82.0
1971	83.0

[a]Measured as the ratio of number of students who had completed rural and primary school to total enrollment. Data developed from DANE, Anuarios Generales de Estadistica [35], Censo de Establicimientos Educativos [34] and Ministerio de Educacion, Informes de Establecimientos Educativos [74].

TABLE XXXIX

COLOMBIA: AGGREGATE DEMAND FOR FARM PRODUCTS, 1950-1971[a]

Year	Demand
(million of 1958 pesos)	
1950	1,183.8
1951	1,974.6
1952	919.4
1953	472.4
1954	1,383.3
1955	749.6
1956	1,413.7
1957	1,292.8
1958	1,370.5
1959	1,953.4
1960	1,474.6
1961	2,116.8
1962	2,026.9
1963	1,987.1
1964	2,557.8
1965	2,338.4
1966	2,833.0
1967	2,393.5
1968	2,395.0
1969	2,431.3
1970	2,298.0
1971	2,551.5

[a]Measured as the value of domestic consumption plus imports and less exports. Data on domestic consumption and exports are from DANE, Boletin Mensual de Estadistica No. 276, July, 1974 [33]. Data on exports are obtained from DANE, Anuarios de Comercio Exterior [36].

TABLE XL

COLOMBIA: INDEX OF WEATHER, 1950-1971[a]

Year	
1950	139.0
1951	118.6
1952	117.1
1953	121.8
1954	130.2
1955	133.8
1956	126.4
1957	101.5
1958	100.0
1959	107.6
1960	129.2
1961	113.6
1962	109.7
1963	109.8
1964	122.5
1965	109.6
1966	123.4
1967	116.6
1968	123.2
1969	128.1
1970	146.2
1971	133.6

[a]Measured as the annual deviation of overall average rainfall during the period, 1950-1971. Data developed from Centro Colombiano de Hidrologia y Metedrologia, Registros Pluviometricos [24].

TABLE XLI

COLOMBIA: ANNUAL RATES OF CHANGE IN PRODUCTION, AREA AND YIELDS, 1950-1971[a]

Crop Product	Production	Area	Yield
	(compound rates of change)*		
Coffee	1.60	1.17	0.43
Cotton (fiber)	14.23	9.02	5.21
Sugar Cane	6.50	3.58	2.92
Non-centrifugal Sugar Cane	5.57	1.62	3.95
Rice	6.19	2.92	3.27
Corn	1.35	0.11	1.24
Plantains	2.91	3.52	-0.61
Potatoes	4.04	3.71	0.33
Cassava	2.36	0.46	1.90
Sorghum[b]	44.43	41.02	3.41
Soybeans[c]	23.00	19.70	3.30
Sesame	5.95	6.75	-0.80
Wheat	-2.88	-5.18	2.30
Kidney Beans	1.52	-1.28	2.80
Cocoa	3.97	2.69	1.28
Tobacco	3.17	1.03	2.14
Banana	2.23	1.44	0.79
Barley	3.80	1.30	2.50

[a]The rates were calculated as the weighted average of the rates of change during 1950-1971, where the weight factors are the length of each period, i.e., 10 and 11 years respectively. Data on production, area and yield obtained from ICA, "Resena de Estadisticas Agropecuarias en Colombia, 1950-1971" [57].

[b]Refers to the 1960-1971 period.

[c]Refers to the 1954-1971 period, divided into the periods 1954-1960 and 1960-1971.

*The method used to measure changes in production, land and yields was as follows:

P = Production, L = Land, and Y = Yield. Then:

$P = (\frac{P}{L}) \cdot L = (Y)(L). \quad dp = d(Y)(L) = (dY)L + Y(dL)$

TABLE XLI (continued)

Dividing both sides by P

$$\frac{dp}{P} = \frac{L}{P}(dY) + \frac{Y}{P}(dL) = \frac{X}{Y.X}(dY) + \frac{X}{X.L}(dL)$$

to get

$$\frac{dP}{P} = \frac{dY}{Y} + \frac{dL}{L}$$

To denote changes over time (t)

$$\frac{1}{dt}\,\frac{dP}{P} = \frac{1}{dt}\,\frac{dY}{Y} + \frac{1}{dt}\,\frac{dL}{L}\ ; \quad \frac{\frac{dP}{P}}{dt} = \frac{\frac{dY}{Y}}{dt} + \frac{\frac{dL}{L}}{dt}\ ; \quad \dot{P} = \dot{R} + \dot{L}$$

where

$$\dot{P} = \frac{\frac{dP}{P}}{dt} = \text{Annual percentage change in production}$$

$$\dot{R} = \frac{\frac{dY}{Y}}{dt} = \text{Annual percentage change in yield}$$

$$\dot{L} = \frac{\frac{dL}{L}}{dt} = \text{Annual percentage change in land.}$$

TABLE XLII

COLOMBIA: INDEX OF LIVESTOCK CAPITAL AND RELATED DATA, 1950-1971
(1958=100)

Year	Beef	Hogs	Sheep	Goats	Total Index[a]	Production per Head[b]	Pasture Land Per Head[c]	Head Per Pasture Land[d]
1950	94.1	141.2	101.0	116.7	100.3	80.8	94.9	105.4
1951	93.3	157.2	104.2	118.6	101.5	74.0	94.2	106.2
1952	92.2	134.3	107.4	120.6	98.7	78.3	96.8	103.3
1953	91.2	124.3	110.7	111.4	96.7	81.4	100.3	99.7
1954	91.3	113.0	107.4	102.2	95.2	89.5	102.3	97.8
1955	93.4	103.0	105.1	93.6	95.2	93.9	103.0	97.1
1956	96.5	97.6	110.1	99.9	97.9	94.9	101.0	99.0
1957	98.4	98.9	105.1	99.9	99.2	97.8	100.4	99.6
1958	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1959	101.7	101.7	94.9	100.9	101.0	103.1	99.5	100.5
1960	101.7	104.5	91.7	100.9	98.5	109.7	104.2	96.0
1961	106.6	107.3	94.9	101.2	105.4	106.7	98.8	101.2
1962	109.7	110.7	98.8	101.4	108.6	108.2	97.5	102.6
1963	111.8	115.1	107.2	101.7	111.4	109.6	95.8	104.4
1964	113.8	123.6	111.4	103.4	114.2	111.8	94.0	106.4
1965	115.5	132.1	115.6	105.1	116.7	111.1	93.4	107.1
1966	117.6	140.6	119.8	106.8	119.7	109.4	91.6	109.1
1967	121.4	149.3	124.1	108.5	124.0	111.3	90.3	110.7
1968	126.4	163.9	125.5	110.9	129.3	112.6	89.2	112.1
1969	131.4	179.4	127.1	113.5	135.1	115.5	88.2	113.4
1970	135.1	196.0	129.0	116.4	139.9	116.5	88.1	113.5
1971	139.1	214.0	131.4	119.9	145.2	118.2	87.0	114.9

[a] A weighted average of the indexes calculated for each kind of livestock with the weights as the relative shares in 1958 of each kind in the total stock of livestock. These factors are 0.78, 0.10, 0.08 and 0.04 for beef cattle, hogs, sheep and goats respectively.

[b] Index of livestock production divided by index of livestock capital.

[c] Index of pasture land divided by the index of livestock capital.

[d] Index of livestock capital divided by the index of pasture land.

Source: Instituto Colombiano Agropecuario, ICA, "Resena de Estadisticas Agropecuarias en Colombia, 1950-1971" [57].

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